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This document has been prepared for the U.S. Army to support the Final Programmatic Environmental Impact Statement for the Chemical Stockpile Disposal Program. This report describes the results of a comprehensive probabilistic assessment of the frequency and magnitude of chemical agent release associated with the storage of chemical munitions at eight U.S. Army installations. Both internal accident initiators (e.g., human error) and external accident initiators (e.g., earthquakes) were analyzed.

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RISK ANALYSIS OF THE CONTINUED STORAGE OF CHEMICAL MUNITIONS

by
GA TECHNOLOGIES INC.

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for the U.S. Army
Office of the Program Executive Officer –
Program Manager for Chemical Demilitarization
Aberdeen Proving Ground, Maryland

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LIST OF ABBREVIATIONS

AAF	Army Air Field
AMC	Army Materiel Command
ANAD	Anniston Army Depot
APG	Aberdeen Proving Ground
BCS	bulk chemical storage
BDS	bulk drain station
BRA	brine reduction area
BSA	buffer storage area
BSR	burster size reduction
CAMDS	Chemical Agent Munition Disposal System
CASY	chemical agent storage yard
CCDF	complementary cumulative distribution function
CHE	cargo handling equipment
CONUS	continental United States
CSDP	Chemical Stockpile Disposal Program
DARCOM	U.S. Army Materiel Development and Readiness Command
DATS	drill and transfer system
Decon	decontaminate/decontamination
DFS	deactivation furnace system
DoD	Department of Defense
DPE	demilitarization protective ensemble
DPG	Dugway Proving Ground
DUN	dunnage incinerator
ECR	explosive containment room
ECV	explosive containment vestibule

EIS	environmental impact statement
EMP	electromagnetic pulse
EPA	expected peak acceleration
FAA	Federal Aviation Administration
FEIS	Final Environmental Impact Statement
FMEA	failure modes and effects analysis
GA	GA Technologies Inc.
HAZOP	hazard and operability analysis
HF	handling operation at the facility
HC	handling operation related to onsite transportation
HP	high pressure
H&R	H&R Technical Associates, Inc.
HRA	human reliability analysis
IE	initiating event
JACADS	Johnston Atoll Chemical Agent Disposal System
LASH	lighter aboard ship
LBAD	Lexington-Blue Grass Army Depot
LIC	liquid incinerator
LPF	leakers processing facility
LPG	liquified propane gas
MDB	munitions demilitarization building
MDM	multipurpose demilitarization machine
MDE	mine demilitarization equipment
MHA	munitions holding area
MHI	munitions holding igloo
MIG	mine glove box
MIN	mine machine
MITRE	The MITRE Corporation
MLD	master logic diagram

MMI	Modified Mercalli Intensity
MPF	metal parts furnace
NA	not applicable
NAAP	Newport Army Ammunition Plant
NDC	National Destruction Center
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
OFC	offsite transport container
ONC	onsite transport container
OPMCM	Office of the Program Manager for Chemical Munitions
ORNL	Oak Ridge National Laboratory
PAS	pollution abatement system
PBA	Pine Bluff Arsenal
PEO-PM Cml Demil	Program Executive Officer-Program Manager for Chemical Demilitarization
PI	periodic inspection
PM	periodic maintenance
PMD	projectile/mortar disassembly
PRA	probabilistic risk assessment
PUDA	Pueblo Depot Activity
RDC	Regional Destruction Center
RDS	rocket drain system
RSM	rocket shearing machine
SAI	Science Applications International Corporation
SEAOC	Structural Engineers Association of California
SMI	storage monitoring inspection
SNL	Sandia National Laboratory
SSE	safe shutdown earthquake
SSI	safety in storage inspection
ST	spray tank

TC	ton container
TEAD	Tooele Army Depot
TECOM	Test and Evaluation Command
THERP	Technique for Human Reliability Analysis
TOX	toxic cubicle
UBC	Uniform Building Code
UMDA	Umatilla Depot Activity
UPA	unpack area

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EXECUTIVE SUMMARY

S.1. INTRODUCTION

S.1.1. Background

Under the direction of the U.S. Army Office of the Program Executive Officer-Program Manager for Chemical Demilitarization (PEO-PM Cml Demil), GA Technologies Inc. (GA) and its subcontractors performed a comprehensive assessment of the frequency and magnitude of accidental agent releases associated with various alternatives under consideration for the Chemical Stockpile Disposal Program (CSDP). This assessment was carried out in support of the environmental impact statement (EIS) for this program and addresses only the stockpile of chemical munitions that is currently stored at eight sites in the continental United States (CONUS). The assessment of potential health consequences to the public resulting from accidental releases calculated in this study will be performed in a separate study. These consequences and the GA-evaluated frequencies of the releases leading to these consequences will form the basis of estimates of the potential public "risks" associated with the CSDP alternatives.

The alternatives investigated in this study are as follows:

1. Disposal of the agents and munitions at the eight existing storage sites.

2. Collocation (transportation) and disposal of the munitions at two regional sites.

3. Collocation and disposal of the munitions at a single national site.

4. Partial collocation of the selected stockpiles from Aberdeen Proving Ground (APG) to Johnston Island by water or to Tooele Army Depot (TEAD) by air and from the Lexington-Blue Grass Army Depot (LBAD) to TEAD by air.

5. Continued storage of the munitions at the existing storage sites.

This report addresses only the continued storage alternative listed above (i.e., item 5). The other alternatives are discussed in separate reports.

S.1.2. Study Objectives and Deliverables

The primary objectives of the study reported in this document were to:

1. Identify events that could initiate the release of agent to the environment (i.e., initiating events).

2. Develop the various sequences of events resulting from these initiators and leading to accidental agent release.

3. Perform a quantitative analysis of the frequency of occurrence of each relevant accident sequence.

4. Characterize the physical state, quantity, and duration of agent released from each accident sequence.

These objectives were accomplished by developing a list of potential accident sequences for each major activity, estimating the frequencies of these sequences, and calculating the magnitudes of released agent associated with these sequences. It should be noted that only accident sequences that survived a conservative screening process, considering both frequency and magnitude of agent release, are included in the deliverables of this project.

S.1.3. Scope of Study

The scope of effort reported in this document, as noted earlier, did not include the evaluation of agent dispersion to the environment and the consequences to the public resulting from such releases. As such, the title of this report is more appropriately that of a probabilistic "release" analysis as opposed to a probabilistic "risk" analysis, since risk is usually defined as the product of frequency and consequence. Therefore, the term "risk," as used in this study, refers to the frequency of accidental agent release and not to the frequency of the agent release consequence to public health.

S.1.4. Site Descriptions

There are eight sites in the CONUS where chemical munitions are currently being stored. These sites are: Tooele Army Depot (TEAD), Anniston Army Depot (ANAD), Aberdeen Proving Ground (APG), Lexington-Blue Grass Army Depot (LBAD), Newport Army Ammunition Plant (NAAP), Pine Bluff Arsenal (PBA), Pueblo Depot Activity (PUDA), and the Umatilla Depot Activity (UMDA).

TEAD is located in north central Utah. A prototype demilitarization plant, the Chemical Agent Munitions Disposal System (CAMDS) facility, is located at this site. The site currently stores a wide variety of chemical munitions and bulk agent containers of mustard and the nerve agents, GB and VX.

ANAD is located in northeast Alabama. The chemical munitions stockpile at ANAD consists of all chemical munitions types except for bombs, spray tanks, and 8-in. projectiles filled with VX.

APG is located in Maryland near the head of the Chesapeake Bay. APG is comprised of two general areas, the Aberdeen area and the Edgewood area where the chemical munition storage facilities are located. Only mustard-filled ton containers are stored at APG.

LBAD is located south of Richmond, Kentucky. The chemical munition stockpile at LBAD consists of 8-in. projectiles, 155-mm projectiles, and M55 rockets.

NAAP is located west of Indianapolis, Indiana. The chemical munitions stockpile is stored there in a single warehouse and consists of containers of VX.

PBA is located southeast of Little Rock, Arkansas. The stockpile at PBA consists of M55 rockets, land mines, ton containers, and some 4.2-in. mortar projectiles.

UMDA is located in northeastern Oregon. The stockpile at UMDA consists of 155-mm and 8-in. projectiles, M55 rockets, M23 land mines, bombs, spray tanks, and ton containers.

S.2. STUDY APPROACH

The risk analysis presented in this report combines the structured safety analysis detailed in MIL-STD-882B (Ref. S-1) and the probabilistic approach outlined in NUREG/CR-2300 (Ref. S-2). The first reference requires that hazards analyses be performed to assess the risk involved during the planned life expectancy of a system. It also provides guidance on the categorization of hazard severity and of probability as a means of identifying which hazards should be eliminated or reduced to an acceptable level. The second reference serves as a guidebook for the risk assessment of nuclear power plants.

Risk assessment can be defined as the quantification of an undesirable effect in probabilistic terms. Relative to the health and safety of the public, the effects of interest are injuries and deaths. Risk assessment has been utilized in various industries for some time. Insurance companies have long used actuarial data for statistical evaluations to justify differences in the insurance premium paid by persons in different "risk" categories. The risk assessments performed for nuclear power plants, on the other hand, are examples of major industry efforts to quantify risks of low-frequency events for which no good actuarial data exist. The nuclear power plant risk assessments have become models for other industrial risk assessments.

S.2.1. Risk Assessment Methodology

Probabilistic risk assessment (PRA) is a systematic, disciplined approach to quantifying the frequency and consequences of events which can occur at random points in time. In its application to the various chemical munition disposal alternatives currently under consideration, PRA provides a comprehensive framework for estimating and understanding the risks associated with the storage, handling, transportation, and demilitarization activities associated with these alternatives. By applying this methodology to each alternative in a consistent and uniform manner, a statement of the relative risk of these alternatives can be made. Because of the significant uncertainties in the data used to quantify the frequency of occurrence of various accident sequences and the magnitudes of the associated agent releases, extreme caution must be used when addressing the absolute risk associated with each disposal option.

In simplistic terms, the PRA process focuses on answering the following three basic questions:

1. What can go wrong?
2. How frequently is it expected to happen?
3. What would be the associated consequences?

The remainder of this summary describes how these questions are addressed in the risk assessment of the chemical material disposal program. In this study, the estimation of consequences is limited to the magnitudes of agent release for each sequence.

S.2.1.1. Identification of Initiating Events. The first step in a probabilistic risk assessment is the identification of initiating events which, by themselves or in combination with additional failures, can lead to the release of agent to the environment. Initiating events are identified for each of the demilitarization activities. Such events generally fall into two broad categories known as "internal" events and "external" events. Internal events originate within the activity and are caused by human error or random equipment failure. Examples of such events are the dropping or puncture of munitions during handling operations, and the random failure of a normally operating piece of equipment in the demilitarization process line. The class of events referred to as external includes aircraft crashes and natural phenomena such as earthquakes and storms. In the context of a risk assessment, events such as internal flooding and fires are also considered to be external events. External events are usually pervasive in nature in that they are assumed to fail redundant equipment that is provided for safe shutdown of the operation and containment of the agent.

S.2.1.2. Accident Sequence Development. Once initiating events are identified, logic models (such as event trees and sequence level fault trees) are developed to display the various paths that the accident can take. For example, an initiating event such as spurious shutdown of an incinerator will not result in a significant release of agent to the environment unless numerous ventilation and automatic shutdown systems fail. In most cases, the probability of failure of multiple systems is so low that the frequencies of such accident sequences are too low to be of any concern. Furthermore, because of inherent system inertia and engineered safety features which are provided, there may be ample time to recover and repair mitigating* systems prior to any release.

As suggested above, operator intervention can influence the course of an accident, and therefore his role must be included in the logic models where appropriate. Of course, operating and emergency personnel also have a significant influence on the potential for and amount of accidental agent release.

S.2.1.3. Human Interactions. Human interactions, or interventions, of interest to the chemical munitions disposal risk assessment fall into one of the following six general categories:

1. Initiation of an accident by committing an error (e.g., a munitions handler punctures or accidentally drops a munition).

2. Test and maintenance actions (e.g., a valve is disabled or left in the wrong configuration following a test or maintenance act).

3. Termination of an accident by correctly implementing established emergency procedures (e.g., an operator terminates agent feed to the liquid incinerator when automatic termination has failed).

4. Aggravation of an accident by taking incorrect action (e.g., a plant operator misdiagnoses the nature of the accident and

*"Mitigation" as used in this report is the act of preventing or limiting the consequence of an accident that has occurred.

performs an act which causes the accident to have greater consequences).

5. Termination of an accident by actions which are outside the scope of existing procedures (e.g., based on his knowledge of the plant or process, a plant operator performs an act which is not covered by procedures and terminates or mitigates the accident).

6. Intentional acts to initiate accidents or render equipment in a failed state (sabotage).

Human interactions that fall in the first three categories are modeled either as a separate event heading in the event tree or as an independent event in the fault tree which is used to model and quantify the event in the event tree. Human interactions defined by categories 4 and 5 above are difficult to quantify and as such are not given much attention in a risk assessment.

Acts of sabotage (category 6) are outside the scope of this analysis and will be addressed elsewhere.

S.2.1.4. Agent Release Characterization. The consequences of an agent-release event are dependent on the type of agent, the magnitude of the release, the mode and duration of the release, the dispersion of the agent to the environment, the demographic characteristics of the region impacted by the release, and the toxicity of the dispersed agent at the concentration levels to which members of the public are exposed. The scope of effort reported in this document is limited to the first three characteristics listed above. Agent dispersion to the environment and subsequent effects on humans are addressed elsewhere in a separate report.

The characterization of agent release required a systematic review of the potential modes of agent release from its normal confinement. The agent release mechanism is dependent on the particular mechanical, thermal, and explosive behavior of the munition, assuming the occurrence of an initiating event such as dropping during handling or aircraft crash, as well as the confinement which is provided, if any.

After determining that agent could be released in a particular accident sequence and that the frequency of that sequence exceeded the threshold screening frequency, an analysis was performed to identify the possible paths by which the agent could be released to the environment and to estimate the quantity of agent released.

S.2.1.5. Sequence Screening. The implementation of PRA methodology in terms of event trees can produce a large number of potential accident sequences. In order to reduce this to a manageable number to focus on the critical scenarios for analysis, the accident sequences are screened for frequency or consequence. By using conservative values for the conditional probabilities of event tree branches, it is possible to show that many of the possible sequences are of sufficiently low frequency (e.g., less than 10^{-10} per year) that they need not be addressed further. In addition, if an accident sequence has a frequency greater than the threshold screening frequency but results in an insignificant release of agent* to the environment, it can also be eliminated from further consideration. The accident sequences contained in this report have been subjected to both types of screening.

*Less than 14 lbm of mustard; less than 0.4 lbm of agent VX; and less than 0.3 lbm of agent GB. These quantities represent the minimum quantities of agent release that would result in a lethal dose of agent at 500 m for the most limiting release modes (Ref. S-3).

S.3. RESULTS

The analysis of the potential for agent release to the atmosphere from accident scenarios related to the continued storage alternative included storage and handling activities. This section discusses some of the accident probability and agent release results associated with these activities.

The results of the analysis of the various activities encompassing the continued storage alternative cannot be presented in the same units, i.e., annual frequencies, because of the possible divulgence of classified information. This is only possible for some storage accident scenarios. For accident scenarios related to the handling activities, the unclassified portion of the probabilistic analysis is given in terms of frequency of accidents per pallet of munitions (or as a container of munitions).

The evaluation of the actual risk to the public and environment requires agent dispersion calculations which are not in the scope of the study reported here. Despite this limitation, the results discussed herein still provide useful insights on the contributions of the various disposal activities to the risk of an agent release. These insights are discussed below.

S.3.1. Accident Scenarios During Storage

The continued storage alternative requires some storage of munitions in their existing location.

S.3.1.1. Internal Events. There were no significant internal event initiators of accidents during storage. Per unit operation, forklift drop accidents occur more frequently than forklift tine punctures. Also, the use of a lifting beam instead of a tine leads to an order of magnitude decrease in drop frequency.

S.3.1.2. External Events. These events involve accidents caused by natural phenomena or human activity affecting munitions in storage igloos, open storage areas, holding areas, or warehouses. If these are assumed to be full of munitions, the agent inventories range up to 100, 200, 1000, and 2000 tons, respectively, for storage igloos, holding areas, open areas, and warehouses. The most frequent external accidents having significant release involve mild intensity earthquakes or small airplane crushes (order depending on site). Amounts of available agent inventories released in these events are on the order of fractions of one percent or less (munition punctures, drops, etc.).

The largest releases occur for a large aircraft crash, a meteorite strike, or a severe earthquake, especially when a warehouse (at NAAP, TEAD, or UMDA) is involved. These can result in up to 10 percent of the agent inventory released for scenarios involving a fire which has the potential (duration) for destroying the entire inventory of an igloo or warehouse. The munitions stored in warehouses contain only VX or mustard which have much slower evaporation rates than GB and hence are not easily dispersed into the atmosphere. Thus, warehouse scenarios involving only spills are not significant risk contributors. The warehouse at UMDA has the potential for the largest release. Meteorite strike-initiated sequence median frequencies are one to two orders of magnitude lower than the aircraft crash-induced sequence frequencies. As expected, munitions stored outdoors are generally more susceptible to large aircraft crashes than those stored in warehouses or igloos, but releases are lower. Both APG and PBA have ton containers stored outdoors, and the aircraft crash probabilities at these sites are somewhat higher than at the other sites. Igloos appear to provide only minimal protection from direct crashes of large planes, but releases are an order of magnitude lower. The releases are more severe if burstered munitions are involved.

S.3.2. Accident Scenarios During Handling

Included in the handling analysis are single munition or pallet movements by hand, forklift, or other equipment.

The results indicate that dropped munitions, whether in palletized form or not, occur more frequently than either forklift tine puncture or forklift collision accidents. In fact, the frequency of forklift collision accidents which lead to the munitions falling off the forklift is an order of magnitude lower than the drop accidents. Furthermore, the type of clothing an operator is wearing while handling these munitions influence the drop frequency value. An operator wearing Level A clothing is more likely to commit an error that would cause the munition to be dropped than when he is wearing more comfortable clothing.

For bare munitions, the rockets seem to be the most prone to punctures from drops or forklift tine accidents.

Bulk items that are punctured lead to larger releases than other munitions such as projectiles or rockets. Bombs are of concern because they contain GB which evaporates more readily than the other agent types. The agent vapor releases range up to 170 lb (thermal failure of all munitions in a pallet).

Handling accidents which lead to significant agent releases (in particular, agent GB) are dominant risk contributors because of the relatively higher annual frequency values. Of course depending on the actual munition inventory, the value of annual frequency may either increase or decrease when converted to the more meaningful per stockpile basis.

S.4. UNCERTAINTIES IN THE ANALYSIS

In assessing the risks associated with the CSDP alternatives, every effort was made to perform best-estimate analyses, i.e., "realistic" evaluation and quantification of the accident sequence frequencies and associated agent releases. The use of pessimistic or conservative modeling techniques or data for quantification violates the intent of the probabilistic nature of the study. Realistic modeling and quantification permits a balanced evaluation of risk contributors and comparison of alternatives. However, for realistic or best-estimate calculations, the obvious concern is the accuracy of the results. Uncertainty analysis addresses this concern.

S.4.1. Sources of Uncertainty

Since the event sequences discussed in Section S.3 have not actually occurred, it is difficult to establish the frequency of the sequence and associated consequences with great precision. For this reason, many parameters in a risk assessment are treated as probabilistically distributed parameters, so that the computation of sequence frequencies and resulting consequences can involve the probabilistic combination of distributions.

There are three general types of uncertainty associated with the evaluations reported in this document: (1) modeling, (2) data, and (3) completeness.

There exist basic uncertainties regarding the ability of the various models to represent the actual conditions associated with the sequence of events for the accident scenarios that can occur in the storage and disposal activities. The ability to represent actual phenomena with analytical models is always a potential concern. The use of fundamental models such as fault trees and event trees is sometimes simplistic because most events depicted in these models are treated as leading to one of two binary states: success or failure (i.e., partial successes or failures are ignored). Model uncertainties are difficult to quantify and are addressed in this study by legitimate efforts of the analysts to make the models as realistic as possible. Where such realism could not be achieved, conservative approaches were taken.

No uncertainty from oversights, errors, or omission from the models used (e.g., event trees and fault trees) is included in the uncertainty analysis results. Including these uncertainties is beyond the state-of-the-art of present day uncertainty analysis.

The uncertainties in the assignment of event probabilities (e.g., component failure rates and initiating event frequencies) are of two types: intrinsic variability and lack of knowledge. An example of intrinsic variability is that where the available experience data is for a population of similar components in similar environments, but not all the components exhibit the same reliability. Intrinsic variations can be caused, for example, by different manufacturers, maintenance practices, or operating conditions. A second example of intrinsic variability is that related to the effects of long-term storage on the condition of the munitions as compared to their original configuration. Lack of knowledge uncertainty is associated with cases where the model parameter is not a random or fluctuating variable, but the analyst simply does not know what the value of the parameter should be. Both of these data uncertainty types are encountered in this study.

S.4.2. Uncertainties

The sequence frequency results discussed in this report are presented in terms of a median value and a range factor of a probability distribution representing the frequency of interest. The range factor represents the ratio of the 95th percentile value of frequency to the 50th percentile (i.e., median) value of frequency. The uncertainty in the sequence frequency is determined using the STADIC-2 program (Ref. S-4) to propagate the uncertainties associated with each of the events in the fault trees or event trees through to the end result. Some scenarios, such as those associated with tornado missiles and low-impact detonations have rather large uncertainties. The difficulty with tornado-generated missiles lies with the difficulty in accurately modeling the probability that the missile will be in the proper orientation to penetrate the munition and in predicting the number of missiles per square foot of wind. The difficulty with the low-impact detonations lies with the sparse amount of data available and its applicability to the scenarios of interest. In general, uncertainties tend to be large when the amount of applicable data is small and vice versa.

S.5. REFERENCES

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S-3. Memorandum to C. A. Bolig (GA) from R. B. Perry (PEO-PM Cml Demil), May 6, 1987.

S-4. Koch, P., and H. E. St. John, "STADIC-2, A Computer Program for Combining Probability Distribution," GA Technologies Inc., GA-A16277, July 1983.

1. INTRODUCTION

1.1. BACKGROUND

The U.S. Department of Defense is required by Congress (Public Law 99-145) to destroy the stockpile of lethal chemical agents and munitions stored at eight U.S. Army installations in the continental United States (CONUS) and at the Johnston Atoll Army site in the Pacific Ocean by the end of September 1994. The locations of the CONUS sites are shown in Fig. 1-1. The total Army stockpile at these sites is made up of more than 3,000,000 items consisting of rockets, mines, mortars, projectiles, cartridges, bombs, spray tanks, and bulk containers. These munitions contain the nerve agents GB and VX and the blistering mustard agents H, HD, and HT

The Army has developed a plan for destruction of the chemical munition stockpile. This plan is set forth in the Chemical Stockpile Disposal Concept Plan submitted to Congress in March 1986 and supplemented in March 1987. In this plan, three disposal alternatives are described:

1. Disposal of the agents and munitions at each of the eight existing storage sites.

2. Collocation and disposal of the munitions at two regional sites.

3. Collocation and disposal of the munitions at a single national site.

These three disposal alternatives were also described in a Draft Progammatic Environmental Impact Statement published by the Army in

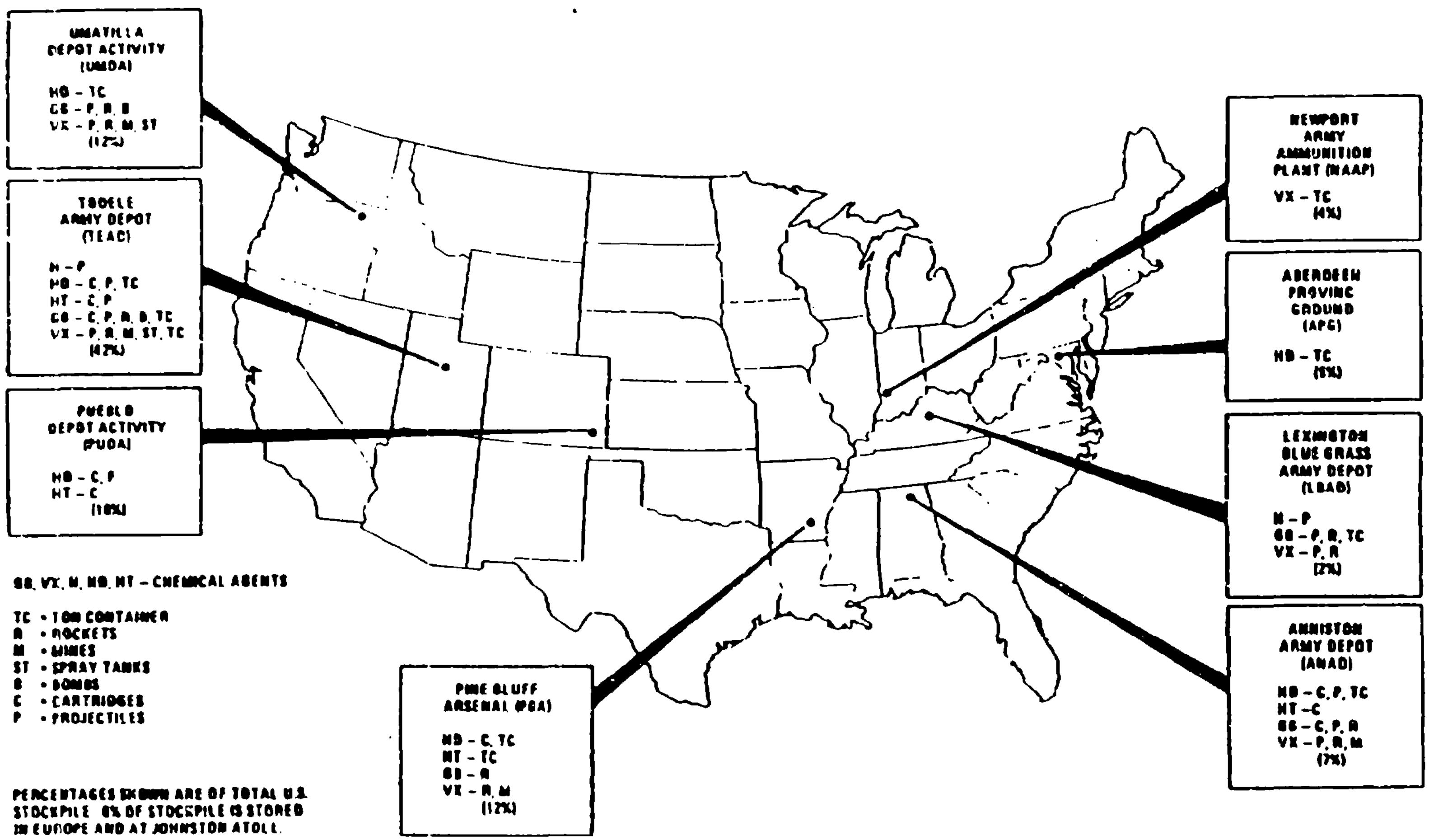

Fig. 1-1. Location of chemical agents and munitions in the U.S.

July 1986. Additionally, it was required that the status quo, i.e., continued storage, be also evaluated as the fourth alternative. As part of the public commentary on this document, requests were made of the Army to consider also the transport of the inventory from Aberdeen Proving Ground to Johnston Island by water or to Tooele Army Depot by air and from the Lexington-Blue Grass Army Depot to Tooele by air.

Under direction from the U.S. Army Office of the Program Executive Officer-Program Manager for Chemical Demilitarization (PEO-PM Cml Demil), GA Technologies Inc. (GA) and other contractors have performed a comprehensive probabilistic assessment of the frequency and magnitude of agent release associated with activities involving the three disposal alternatives currently set forth in the Chemical Stockpile Disposal Program (CSDP), as well as the continued storage alternative. This assessment has been carried out in support of the environmental impact statement (EIS) for this program and it addresses only the stockpile of chemical munitions which are currently stored at the eight sites located in the continental United States (CONUS).

When combined with an assessment of the consequences (injuries and/or deaths) to the public resulting from the accident sequences and associated agent releases identified and evaluated in this study, the results form a basis for an assessment of public risk. The dispersion of the agent to the environment and the assessment of consequences related to these releases are outside the scope of this study. A consequence assessment has been performed by MITRE Corporation and Oak Ridge National Laboratory for the EIS, based on the releases identified in this document.

This report addresses only the alternative of continued storage. The remaining alternatives are discussed in separate reports.

Previous studies have been utilized by GA as reference bases for this assessment. Quantitative hazards analyses were performed by

Arthur D. Little, Inc. on the disposal of M55 rockets (Refs. 1-1 to 1-5), and qualitative hazards analyses were performed by the Ralph M. Parsons Company on the Johnston Atoll Chemical Agent Disposal System (JACADS) design (Refs. 1-6 and 1-7). In addition, a probabilistic analysis of chemical agent release during transport of M55 rockets has been performed by H&R Technical Associates (Ref. 1-8), and a probabilistic analysis of selected hazards during the disposal of M55 rockets has been performed by Science Applications International Corporation (Ref. 1-9). These studies provided the set of accident scenarios that was compiled in a systematic order by MITRE Corporation (Refs. 1-10 and 1-11). GA, in turn, used these accident scenarios as a starting point in this study.

The analyses performed by Arthur D. Little, Inc. used a technique known as hazard and operability analysis (HAZOP). HAZOP involves a detailed review of plant design to trace all parts and functions of the demilitarization process. For each piece of equipment or pipe run, deviations from normal operating conditions were examined and possible consequences were discussed. Through this approach, potential failure modes leading to agent release outside of the facility were identified. The expected frequencies of occurrence of all agent release sequences identified in the HAZOP were then evaluated using fault tree analysis.

The qualitative hazards analysis performed for JACADS used an approach known as failure modes and effects analysis (FMEA). The severity and probability levels of identified hazards were ranked according to the guidelines in Ref. 1-12.

The transportation studies performed by H&R Technical Associates (Ref. 1-8) used a combined fault tree and event tree approach to assess the frequency of agent release from transportation accidents.

The work performed by Science Applications International Corporation (Ref. 1-9) on the disposal of M55 rockets utilized both event tree and fault tree methodology as used in the PRA of nuclear power plants.

1.2. STUDY OBJECTIVES AND SCOPE

The primary objectives of the study reported in this document were to:

1. Identify events (for each major activity) that could initiate the release of agent to the environment.

2. Develop the various sequences of events resulting from these initiators and leading to agent release.

3. Perform a quantitative analysis of the frequency of occurrence of each relevant accident sequence.

4. Characterize the form, quantity, and duration of agent release from each accident sequence.

5. Identify accident sequences which make the most significant contributions to risk.

The major deliverables of this effort are a list of potential accident sequences for each major activity, the estimated frequencies of these sequences, and the magnitudes of released agent associated with these sequences. It should be noted that only accident sequences that survived a conservative screening process, involving both frequency and magnitude of agent release, are included in these deliverables.

This report addresses each of the objectives listed above and presents the analysis of this study. The risk analysis includes an evaluation of potential accidents and natural occurring phenomena such as earthquakes and tornadoes. Acts of war, sabotage, and terrorism, which involve intentionally-initiated events, were not included in the scope of this effort.

The term "chemical munitions" is used here to describe both burstered chemical munitions and chemical bulk items. The 4.2-in. mortars refer to the actual 4.2-in. projectile which is fired from mortar cannons or tubes. The 105-mm cartridge and 4.2-in. mortar projectile can either be configured with propellant (i.e., a cartridge) or without propellant (i.e., a projectile); in this study, it was assumed that the propellant and fuze were removed prior to the onset of the disposal program.

1.3. DEMILITARIZATION ACTIVITIES AND SAFETY CONCERNS

Figure 1-2 shows a comparison of the various logistics phases associated with the various munition disposal and storage alternatives evaluated for the EIS. As indicated in this figure, the demilitarization process associated with the continued storage option involves only those events related to long-term storage.

The hazards of interest are those involving the evaporative release of agent to the environment resulting from spills, leaks, and mechanical failures, and the release of agent to the environment resulting from fires and explosions. The generation of these potential hazards originates with a number of "internal" and "external" initiating events. The number of hazard-initiating event combinations is rather extensive. However, because of the screening process which was used to remove from further consideration the accident sequences whose frequency was low and/or the associated magnitude of agent release was low, the number of individual sequences which are important to risk is relatively small.

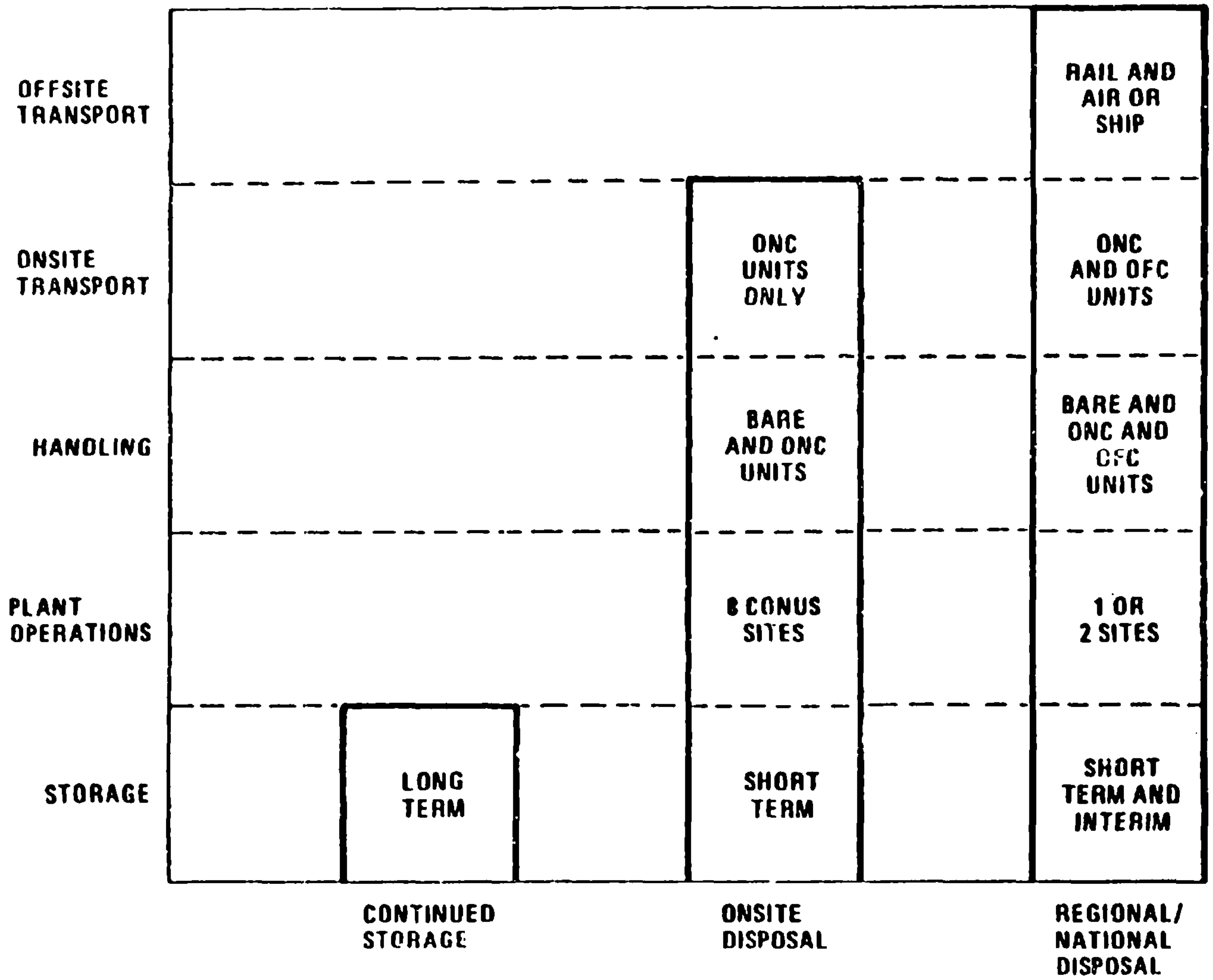

Fig. 1-2. Logistic phases associated with the munitions storage and disposal options

1.4. STUDY ASSUMPTIONS

The risk analysis presented in this report uses an approach that combines the structured safety analysis detailed in MIL-STD-882B (Ref. 1-12) and the probabilistic approach used in the safety analyses of nuclear power plants (Ref. 1-13). Reference 1-12 requires that hazards analyses be performed in order to assess the risk involved during the planned life expectancy of a system. It also provides some guidance on the categorization of hazard severity and probability as a means of identifying which hazards should be eliminated or reduced to a level acceptable to the managing activity.

The risk analysis was performed under the following set of general assumptions:

1. Munitions will be stored in their current storage locations.
2. Munitions are in good condition.
3. Sabotage or terrorism is not considered.

A detailed listing and discussion of assumptions is presented in Appendix E.

1.5. REPORT FORMAT

This report is structured as outlined schematically in Fig. 1-3. The structure follows that typically used in comprehensive probabilistic risk assessment (PRA) studies.

Following the introduction in Section 1 of this report, Section 2 provides a summary of the methodology used in this assessment, including the procedure for accident scenario identification and screening, the approach used for quantifying accident frequencies and characterizing agent release, and the treatment of uncertainties.

Section 3 provides a brief discussion of the various activities involved in the continued storage of chemical munitions. This discussion is provided to assist readers in the understanding of the initiating events and accident scenarios that have been identified and are discussed in Section 5. Section 3 also discusses site-specific information that is important to a particular site. Appendix D contains additional site information.

The list of accident initiating events which have been analyzed is along with the analysis of their occurrence frequencies are presented in Section 4. These events include accidents from internal causes, such as inadvertent impact during handling, and accidents caused by external events, such as earthquakes or aircraft crashes.

Section 5 presents the detailed development and analysis of the key accident scenarios resulting from the initiating events.

Section 6 provides the basis for quantification of accident sequence frequencies including munition failure probabilities, the data base used for estimating the probabilities of event-tree top events and fault-tree basic events, and the data used for assessing human error.

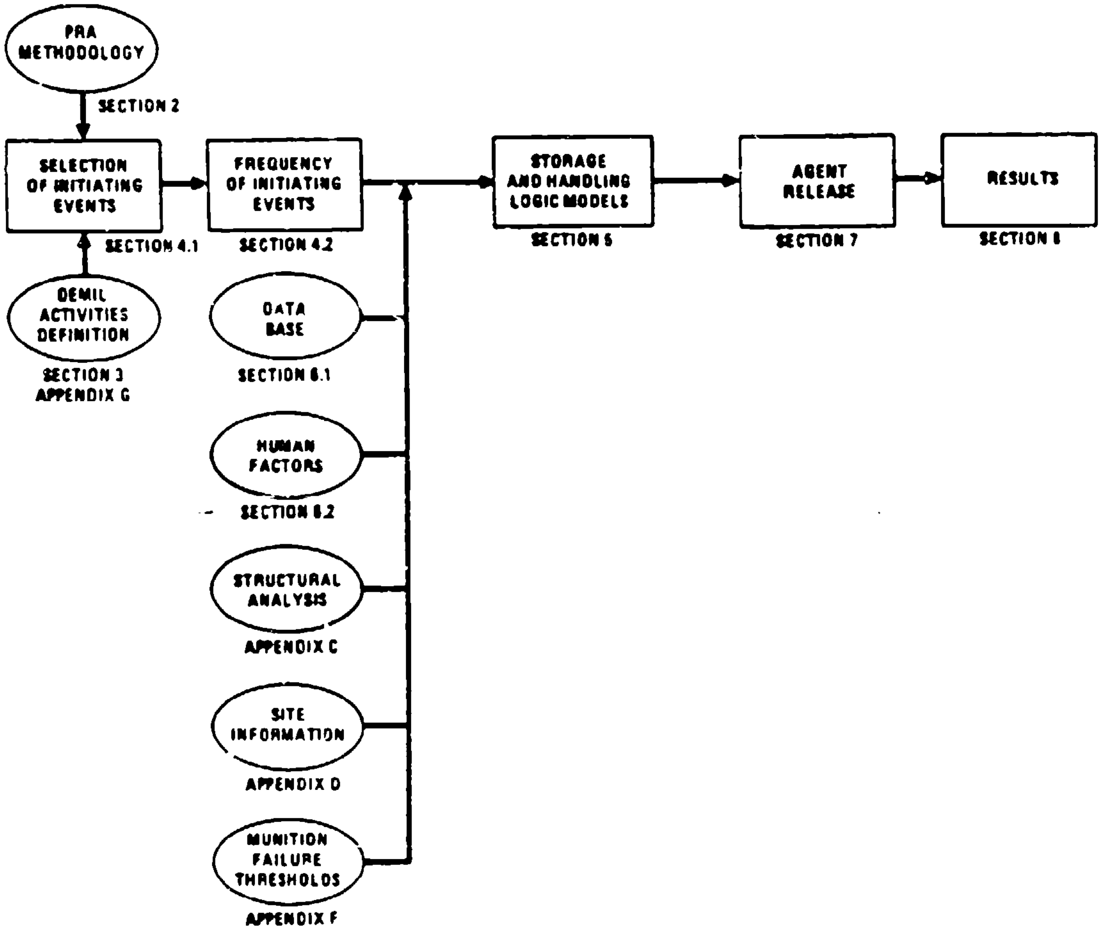

Fig. 1-3. Outline of report structure

The characterization of agent released in the various accident sequences is discussed in Section 7.

Section 8 presents the overall results of the analysis.

Supporting data and calculations for the study are contained in the appendices. References to appropriate appendices are made throughout the body of the report.

1.6. REFERENCES

1-1. Arthur D. Little, Inc., "Analysis of Risks Associated with Operation of Onsite M55 Rocket Demilitarization Plants," U.S. Army Toxic and Hazardous Materials Agency, M55-OD-3, May 1985.

1-2. Arthur D. Little, Inc., "Analysis of Risks Associated with Operation of the JACADS M55 Rocket Demilitarization Plant," U.S. Army Toxic and Hazardous Materials Agency, M55-OD-9, May 1985.

1-3. Arthur D. Little, Inc., "Analysis of Converted M55 Rocket Demilitarization Plant at Pine Bluff Arsenal," U.S. Army Toxic and Hazardous Materials Agency, M55-OD-10, May 1985.

1-4. Arthur D. Little, Inc., "Analysis of Risks Associated with Operation of the CAMDS M55 Rocket Demilitarization Plant," U.S. Army Toxic and Hazardous Materials Agency, M55-OD-11, May 1985.

1-5. Arthur D. Little, Inc., "M55 Rocket Separation Study," U.S. Army Toxic and Hazardous Materials Agency, M55-OD-08, November 1985.

1-6. The Ralph M. Parsons Company, "JACADS-Preliminary Hazards Analysis of Final Concept Design," Task G-56 Interim Report, May 1983.

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1-8. Rhyne, W. R., et al., "Probabilistic Analysis of Chemical Agent Release During Transport of M55 Rockets," H&R Technical Associates, Inc., Prepared for USATHAMA, M55-CD-4, H&R 255-1, September 1985.

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1-10. Fraize, W., et al., "Preliminary Risk Analysis Supporting the Chemical Weapons Stockpile Disposal Program (CSDP), Volume 1: Analysis," The MITRE Corporation, MTR-86W4-01, May 1987.

1-11. Fraize, W., et al., "Preliminary Risk Analysis Supporting the Chemical Stockpile Disposal Program (CSDP), Volume 2: Appendices," The MITRE Corporation, MTR-86W4-01, May 1987.

1-12. U.S. Department of Defense, "Military Standard System Safety Program Requirements," MIL-STD-882B, March 30, 1984.

1-13. U.S. Nuclear Regulatory Commission, "PRA Procedure Guide," NUREG/CR-2300, 1982.

2. RISK ASSESSMENT METHODOLOGY

2.1. OVERVIEW

The probabilistic risk assessment (PRA) methodology used in this study is generally consistent with the PRA Procedures Guide (Ref. 2-1) for nuclear power plants. Figure 2-1, adapted from that guide, outlines the risk assessment procedure for this study. Certain specific features of the chemical munition accidents dictate some different emphasis and treatments from those described in Ref. 2-1. The risk assessment steps corresponding to the procedures in Fig. 2-1 are as follows:

1. Identify accident initiators (initiating events) through information collection, hazards analyses, or the use of master logic diagrams. The initiating events are classified as external if they originate from outside the munition storage and maintenance process (such as aircraft crash) and as internal otherwise.

2. Define accident scenarios, i.e., combinations of initiating events and the successes or failures of systems that respond to the initiating event. An "accident sequence" is referred to in this report as a specific end point of an accident scenario, which is usually modeled using event trees. An "event tree" is an inductive logic model which traces the sequence of events that can occur following an initiating event.

3. Construct "fault trees" (deductive system logic models) to determine the root causes of individual system failures. The fault tree is reduced to minimal cut sets using Boolean algebra. A "minimal cut set" represents a unique combination of events leading to system failure.

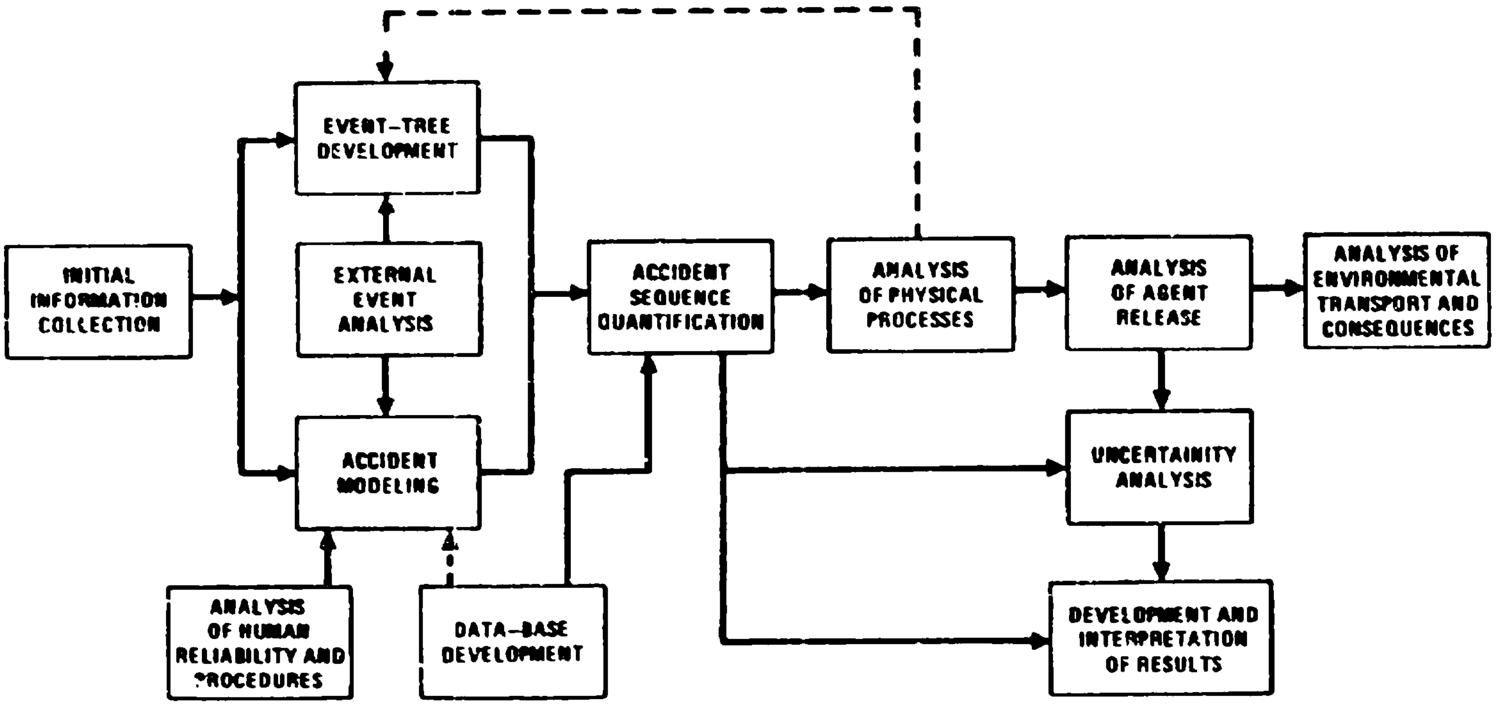


Fig. 2-1. Outline of risk assessment procedure used in this study

4. Assign failure rates or probabilities to events (components or subsystem) modeled in the event trees and fault trees. Quantify the frequencies of occurrence of accident sequences from either the event tree or fault tree by computing the product of the initiating event frequency and the probabilities of the subsequent conditional events in a given accident scenario.

5. Determine the consequences of the accident sequences. In this analysis, the consequence of concern is the amount of agent released to the local free environment. The impact of agent release on the population will be used by others in their CSDP analysis.

6. Evaluate the uncertainties in the data base, and predict the uncertainty in each relevant accident sequence frequency by propagating the top event uncertainties through the event trees.

7. Present the results (i.e., accident scenario frequency and consequence) in a form that will best show those sequences that are important to risk and will reflect the uncertainties associated with the accident sequence frequency.

2.2. INITIATING EVENTS

An initiating event (IE) is a single occurrence or malfunction that has the potential to release one or more agents or to start a sequence of events that could lead to a release. The list of IEs is developed based on previous demilitarization studies (Section 1.2) and related PRAs such as Waste Repository studies (e.g., Ref. 2-2), in addition to the use of master logic diagrams.

The IE list is developed in top-down fashion by structuring a master logic diagram to define a functional set of initiating categories. These categories form a complete set in the sense that any event which leads to agent release must cause at least one of these categories to occur.

Some "common cause initiating events" (e.g., an earthquake) can activate more than one initiating event category and disable controls for release. While there is no way to guarantee that all such events are identified, two areas yield the most significant events. The first includes severe environmental events (such as fire, flood, earthquake, and wind) as well as hazardous activities in the vicinity (such as aircraft patterns). The second area includes malfunctions that can affect multiple controls or barriers for the prevention of release to the atmosphere.

Coincident with the development of the list of initiating events is the assessment of the initiating event frequencies. This is required, first, for subsequent quantification of event trees, since the event initiator is the first even of the tree. Second, it enables screening of the list of initiating events, i.e., events having extremely low frequencies can be eliminated. Where possible the IEs are grouped into categories when the subsequent event tree and release analysis development is the same for all IEs in the category. This grouping is performed by Boolean summation of the occurrence frequencies, accounting for dependencies, if any.

2.3. SCENARIO DEVELOPMENT AND LOGIC MODELS

Given the occurrence of an initiating event, accident scenarios are developed, in many cases using logic models of either event trees, fault trees, or both, to arrive at the various outcomes of the scenario progression. Each of these outcomes, termed a sequence, is associated with (or even characterized by) a certain level of agent release. The basic premise of the risk summation process is that release frequencies (initiating event frequency multiplicatively combined with probabilities of subsequent failures necessary to get the release) of entirely different sequences can be additively combined to get the overall frequency of release. The additive and multiplicative combination is performed using Boolean algebra and accounts for dependencies.

Figure 2-2 shows a sample event tree. In this example, the IE is a vehicle collision, having an estimated occurrence frequency which can be a point estimate or be probabilistically distributed. The IE is the first "top event," and potential subsequent failures represent the other top events or branch points. These top events are in the form of questions, and by convention the upper branch represents the positive answer sequence and the lower branch is the negative answer sequence. Branch split fractions or probabilities are assigned at each of these branch points. These split fractions may be point estimates or probabilistic distributions, and may not be the same for all branch points under a specific top event, depending on prior events. That is, the split fractions represent conditional probabilities.

The frequency of an accident sequence is calculated based on the following equation:

$$F_j = I_j \prod_{i=1}^{n} P_{i,j} \quad , \qquad (2\text{-}1)$$

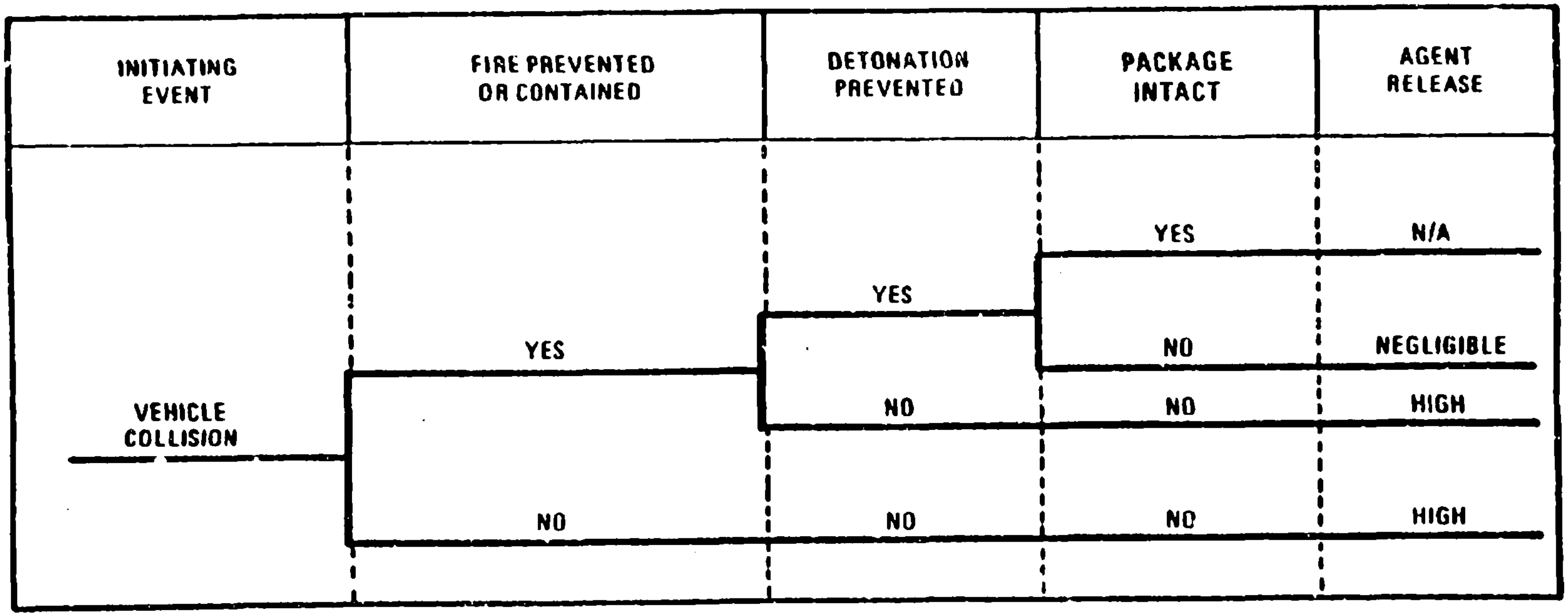


Fig. 2-2. Accident scenario development using an event tree

where F_j = frequency of accident sequence j,

I_j = initiating event frequency,

$P_{i,j}$ = conditional probability of sequence event i following an initiating event, I_j.

Accident frequency and equipment/component failure rate data were derived from various sources, as described in Section 9.

In this study, the event trees are relatively simple in form compared to those developed for nuclear plant PRAs. Most dependencies are modeled explicitly in the event trees by use of conditional branching probabilities which are dependent upon the branch taken for prior events. For example, in an event tree where two consecutive top events represent the availabilities of systems 1 and 2, system 2 might not be called upon unless system 1 fails. This would be shown in the event tree by a dashed line for system 2 in the system 1 success branch, indicating not applicable. Conversely, if system 2 is capable of operating only in conjunction with successful operation of system 1, the dashed line is shown on the system 1 failure (no) branch for system 2 top event. This indicates a guaranteed failure of system 2, given nonoperation of system 1.

For many scenarios, it was found convenient to use fault tree logic for development of the accident progression and quantification of the sequence frequencies. Figure 2-3 depicts a sample fault tree. Logic symbols used in constructing fault trees are defined in Fig. 2-4. The approach taken for treatment of dependencies in the event trees is to identify specific intercomponent and intersystem causes of multiple failures, if any, directly in the fault tree and to make an allowance for those not explicitly identified. A Beta factor method (e.g., Ref. 2-3) is a convenient tool for determining a suitable allowance and was used where appropriate. In this method, multiple failures of redundant components are assumed to occur in a dependent fashion; the

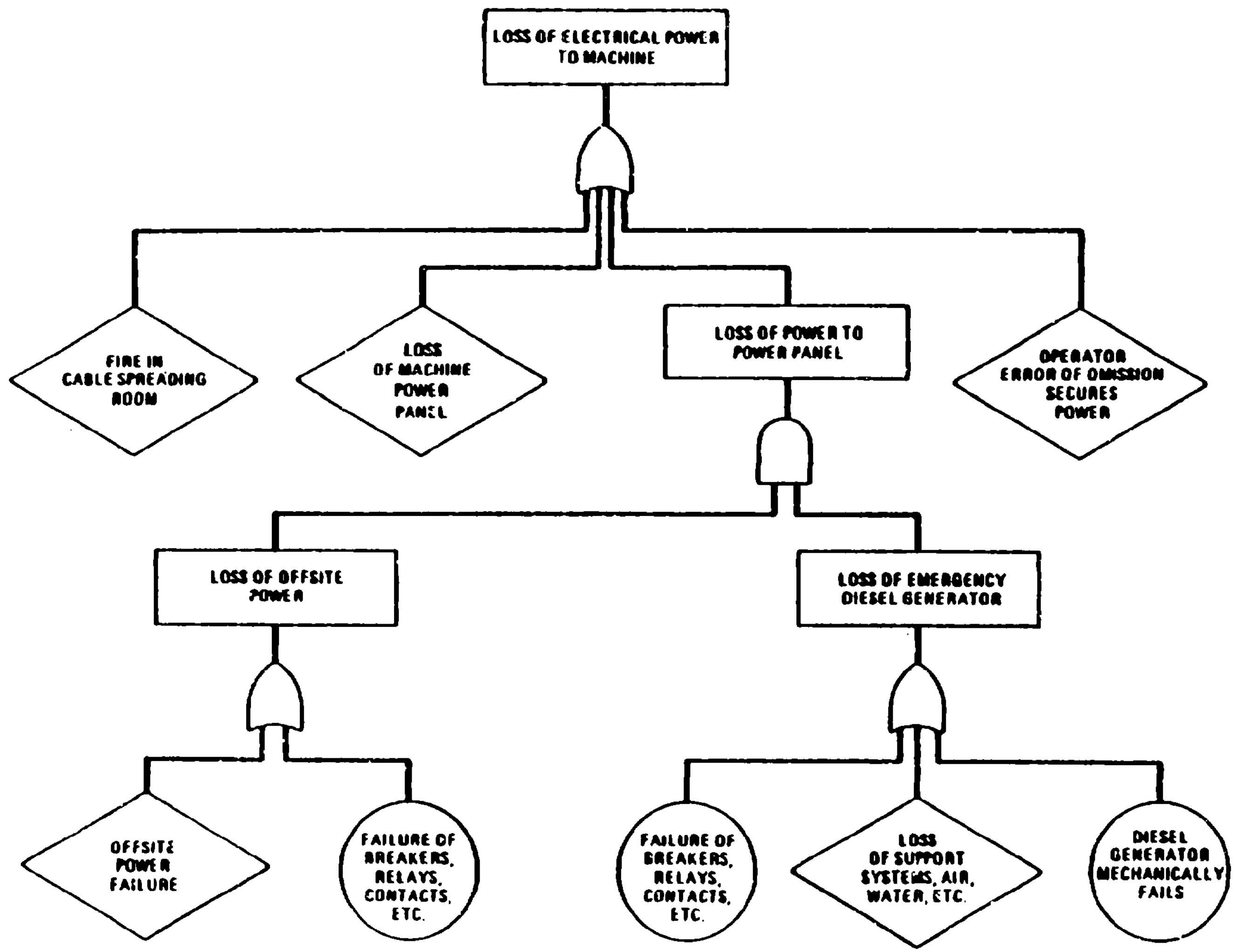


Fig. 2-3. A fault tree model of a power system failure

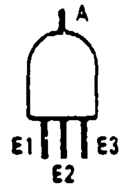
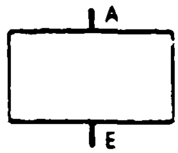
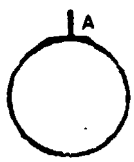
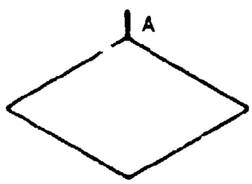
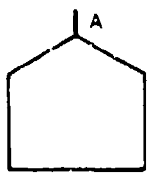
	"AND"	OUTPUT (A) EXISTS ONLY WHEN ALL INPUTS (E) EXIST. THE NUMBER OF INPUTS MUST BE AT LEAST TWO. INDICATES REDUNDANCY. $P(A) = P(E1) \times P(E2) \times P(E3) \times$ ETC.
	"OR"	OUTPUT (A) EXISTS WHEN ONE OR MORE INPUTS (E) EXIST. THE NUMBER OF INPUTS MUST BE AT LEAST TWO. $P(A) = P(E1) + P(E2) + P(E3) +$ ETC.
	"RESULTANT FAULT EVENT"	THE FAULT CONDITION THAT EXISTS WHEN INPUT (E) EXISTS.
	"BASIC INPUT EVENT"	A SPECIFIC FAILURE TO WHICH A FAILURE RATE OR RELATIVE PROBABILITY CAN BE ASSIGNED. OUTPUT (A) EXISTS WHEN THE FAILURE EXISTS.
	"UNDEVELOPED EVENT"	SUBSTITUTE FOR A BASIC INPUT EVENT WHEN THE FAILURE IS NOT TRACED TO A SPECIFIC SOURCE. THIS SYMBOL CAN REPRESENT ANOTHER FAULT TREE AT A LOWER LEVEL WHICH HAS NOT BEEN DRAWN.
	"HOUSE"	THE HOUSE REPRESENTS AN EVENT WHICH IS NORMALLY EXPECTED TO OCCUR OR NEVER TO OCCUR. IT IS TREATED AS A SWITCH ON THE TREE AND IS SET ON OR OFF.
	"TRANSFER"	INDICATES TIE-IN TO A SEPARATE FAULT TREE.

Fig. 2-4. Definition of fault tree symbols

parameter β is defined as the fraction of failures experienced in components that are common cause failures.

Just as there are uncertainties in estimating component failure rates, there are also uncertainties in the β factor. These uncertainties were quantified assuming a lognormal distribution for the β factor. The uncertainty distribution accounts for uncertainties due to sparsity of data, as well as those due to classification and the so-called "potential common cause failures." These are events in which one failure actually occurs and additional failures could have occurred under different circumstances, as well as incipient failures and degraded operability states.

In the case where the fault sequence i, given an initiating event, involves a subsystem or equipment failure, the failure probability calculations may involve not only the calculation of the unavailability value (probability of failure per demand) but also the unreliability value (probability of failure while component/equipment is running). In this case, the overall failure probability value for a given equipment or subsystem is calculated using the following equation (Ref. 2-3).

$$P_i = P_{i,d} + (1 - P_{i,d})\, P_{i,r} \quad , \qquad (2\text{-}?)$$

where $P_{i,d}$ = failure upon demand (unavailability),

$P_{i,r}$ = failure while running (unreliability).

The calculation of component unavailability ($P_{i,d}$) is influenced by several factors: (1) the frequency of periodic maintenance (PM); (2) the use of different failure detection systems; and (3) the various methods used to monitor equipment operation.

For the analysis presented in this report, two options were considered in the calculation of component unavailability. The first option is to consider the periodic maintenance of a component. Thus, when a component is periodically removed from service for preventative maintenance, the failure probability is dominated by the maintenance interval in addition to the failure rate according to the following equation:

$$P_{i,r} = \frac{1}{\lambda\theta}\,(1 - e^{-\lambda\theta}) \approx \frac{\lambda\theta}{2} \quad , \tag{2-3}$$

where λ = failure rate,

θ = maintenance interval,

The second option was to consider continuous component surveillance which decreases the failure probability by announcing component failure to the operators concurrent with failure initiation. The repair time required to restore the component becomes an important factor as shown in the following equation:

$$P_{i,r} = \frac{\lambda}{\lambda + \nu}\,[1 - e^{-(\lambda+\nu)t}] \quad , \tag{2-4}$$

where ν = $1/\tau$ mean repair rate (per h),

τ = repair time (h),

t = time interval of interest (h).

In Eq. 2-4 the failure probability approaches $\lambda\tau$ as the time interval increases and $\lambda\tau$ is small (i.e., $\lambda\tau \ll 1$).

In most of the component failures identified in the fault tree models, the first option is used and a monthly maintenance interval is assumed (i.e., interval of 528 h) for the equipment. This is a conservative approach in deriving the failure probability. If a more frequent maintenance policy is adopted or if experience shows that the component restoration time is much less than the maintenance interval, the failure probability will decrease. However, in view of the nature of the fault tree models, this approach seems justified because the failure contribution of a particular component is not negated by assuming an unnecessarily low failure probability.

2.4. HUMAN FACTORS

The treatment of intersystem and intercomponent equipment dependencies is discussed above, including how the dependencies are taken into account by the logic models. This section describes another kind of dependence--that involving human interaction.

To the extent that human beings design, construct, operate, and maintain the plant, it is impossible to fully isolate the role of human interactions from any of the dependencies discussed above in terms of hardware interactions. Hence, all of the common cause analysis methods described above pertain directly or indirectly to human interactions. The discussion is restricted here to human interactions in the operation and maintenance processes.

The procedure for analysis of intersystem and intercomponent dependencies caused by human interactions was to include human errors of omission and commission explicitly in the event tree/fault tree models and to use the human reliability methods of Swain (Ref. 2-4) to implement quantification. A starting point for the identification of specific errors is the analysis of operation and maintenance procedures if they have been defined for the event sequence being investigated. This is especially important if operator action is required to effect actuation of a system or a collection of systems. Consideration needs to be given to possible incorrect judgments as to the plant state and subsequent implementation of the wrong procedures. Once these acts are identified and modeled, the problem of determining contribution to risk by operator actions is reduced to assigning the correct human error rate values.

2.5. RELEASE CHARACTERIZATION

The risk associated with each accident scenario requires not only the quantification of the frequency of that scenario but a characterization of the agent release as well. This characterization involves the type and amount of agent released, plus the mode and duration of the release.

At any given time, there is at least one containment barrier separating the agent from the surrounding environment. Thus failure or loss of integrity of this barrier must occur for agent to be released to the environment.

In general, the accident scenarios of interest are those scenarios in which the agent is initially inside the munition. There are essentially three types of agent release to the environment:

1. Evaporation from a liquid spill.
2. Releases resulting from detonations.
3. Releases resulting from fires.

Various combinations of these releases appear in many of the scenarios. In addition, depending on the location of these events (e.g., indoor versus outdoor spills), the evaporation rates governing these releases may vary somewhat.

The approach taken for assessing the amount, type, and duration of agent release is based on deterministic models which stem from previous demilitarization safety studies described in Section 1.1. These models are based largely on data but also engineering judgment. They are described in Section 10.1.

Elements of the model include correlations for evaporation release, based on the D2PC computer program. In many cases, the D2PC computer program was used directly to calculate evaporative releases. Other elements include the fraction of burning agent which is released as vapor and the fraction of a detonating munition inventory which is released as vapor. The model relies heavily on data and analysis of munitions failure thresholds, summarized in Appendix F, to determine the extent of munition failures, including the potential for failure propagation of munitions. It is this area where engineering judgment was needed to supplement the data and analysis. Where judgmental factors entered in, they were routinely made in a conservative manner to cover possible uncertainties.

2.6. UNCERTAINTY ANALYSIS

Estimates of failure probabilities derived from various data sources are subject to uncertainties. Data sources do not always specify what failure modes are represented, what operating environment is applicable, or what is the total statistical population. In some cases, failure data may not be available for a specific event; therefore, data for events that occur under conditions that are similar to the events under consideration are selected as representative. These considerations result in uncertainties that are reflected in the range of possible numerical values for an event.

For events involving equipment failures, a lognormal distribution was assumed to define the uncertainty in the failure probability. The lognormal distribution was explicitly used in Ref. 6-18 and other PRA studies of nuclear power plants because of its mathematical behavior. For the analysis covered in this report, equipment failures and accident initiators that are either man-made or arise from natural causes are assumed to be lognormally distributed.

In the analysis of accident scenario probabilities, the STADIC-2 computer program (Ref. 2-5) was used to combine probability distributions of a series of event sequences which make up an accident scenario. STADIC-2 uses a Monte Carlo simulation technique to generate a pseudo-random sample statistical distribution for a user-defined output function. Each input variable exhibits random, statistical variations that are represented by a particular probability distribution (lognormal, normal, etc.). The statistical distribution for the output function (and accident scenario probability in this case) is generated by combining the distributions in accordance with the mathematical operations specified by that function. This combining of distributions is accomplished as follows:

1. Each Monte Carlo sample consists of selecting one pseudo-random sample value for each input variable from its corresponding statistical distribution.

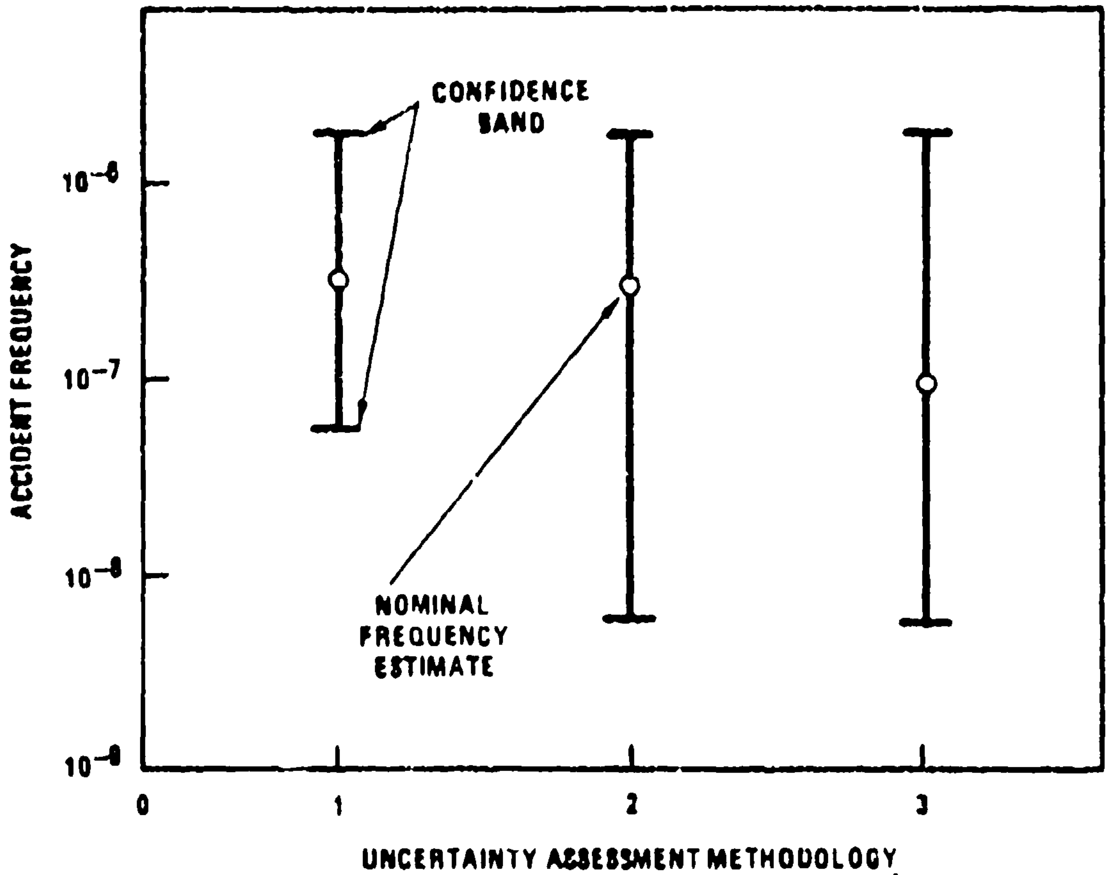
2. The set of sample variable values are mathematically combined to find the corresponding value of the function.

3. Sampling is continued in this manner until the desired sample size is attained.

4. The results consist of the pseudo-randomly generated values of the output function.

Probabilistic data base uncertainties are the only uncertainties explicitly quantified in this analysis. Although data base uncertainties are important, the accident frequency calculations are also sensitive to assumptions incorporated into the probabilistic assessment. Since the uncertainties in these assumptions are extremely difficult to quantify, conservative assumptions are consistently used in this risk analysis.

Figure 2-5 depicts the impact of this methodology (identified as Method 1 in the figure) on the accident frequency assessment results. Essentially, this methodology produces a conservative, nominal frequency estimate, and underestimates the size of the confidence bands. However, the error associated with the confidence band estimate primarily results in predicting a much higher value for the lower confidence band than actually exists (compare the results of Methods 1 and 3 in Fig. 2-5). Hence, the uncertainty assessment methodology employed in this analysis overestimates nominal accident frequencies and the confidence in the predicted frequency.



METHOD	DESCRIPTION
1	CONSERVATIVE ASSUMPTIONS, ONLY DATA BASE UNCERTAINTIES QUANTIFIED
2	CONSERVATIVE ASSUMPTIONS, ALL UNCERTAINTIES QUANTIFIED
3	REALISTIC ASSUMPTIONS, ALL UNCERTAINTIES QUANTIFIED

Fig. 2-5 Impact of assumptions on the accident frequency uncertainty assessment

No quantitative uncertainty analysis is performed for the agent release calculations, due to the complexity involved in such an assessment. Instead, conservative releases are calculated.

2.7. REFERENCES

2-1. U.S. Nuclear Regulatory Commission, "PRA Procedures Guide," NUREG/CR-2300, 1982.

2-2. GA Technologies Report for Sandia National Laboratories, "High-Level Waste Preclosure Systems Safety Analysis Phase II Progress Report," GA-C18557, August 1986.

2-3. Fleming, K. N., "A Reliability Model for Common Mode Failures in Redundant Safety Systems," Procedures of the Sixth Annual Pittsburgh Conference on Modeling and Simulation, April 1975.

2-4. Swain, A. D., and H. E. Guttman, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications," SNUREG/CR-1278, SAND 80-0200, August 1983.

2-5. Koch, P. and H. St. John, "STADIC-2, A Computer Program for Combining Probability Distributions," GA Report GA-A16777, July 1983.

3. CONTINUED STORAGE DESCRIPTION OVERVIEW

Chemical munitions are currently stored at eight CONUS sites (Fig. 1-1). A description of the CONUS sites, including local maps, is given in Appendix D. Section 3.2 provides a summary description of the munitions.

A detailed discussion of the long-term storage and handling operations associated with the continued storage option is presented in Appendix G. Section 3.1 provides a summary of these activities as they relate to the risk study.

3.1. CONTINUED STORAGE ACTIVITIES AND RISKS

The major activities for the continued storage option involve long-term storage as well as handling activities associated with surveillance and maintenance. They are discussed in the following paragraphs.

3.1.1. Storage

During storage, the only planned activities are monitoring for leakage, surveillance maintenance and repair of munitions in the stockpile. Internal events for storage thus address leakage between inspections and munition drop or forklift tine puncture during munition handling. The stored munitions are susceptible to external events, such as fire, tornado, aircraft or meteorite crash, earthquake flood, and lightning.

3.1.2. Handling

Basically, the risks associated with handling operations stem from accidents caused by equipment failures or human error. The types of accidents are: vehicle collisions, forklift tine punctures, and drops of munitions. The munitions affected may be single, in bare pallets, or in a container. The locations of the agent release may be indoors, or in the open (outdoors). Externally caused handling accidents were not considered in this analysis because of the short time spans for actual outdoor handling operations.

3.2. MUNITIONS DESCRIPTION

This section describes the munitions that comprise the CONUS munitions stockpile. The munitions stored at each site are summarized in Fig. 1-1. As indicated the inventory of munitions and bulk agent in storage differs greatly from site to site. Detailed information on the precise numbers of chemical agent munitions at each site is classified except for the information on M55 rockets. All of the chemical munitions in storage are at least 18 yr old (production of new chemical munitions was stopped in 1968), and some are more than 40 yr old.

The munitions stockpile consists of 11 different munition types. A detailed description of each munition type, including a discussion of their thresholds, is presented in Appendix F. A brief description of the munitions follows.

3.2.1. Rockets

The M55 rockets are filled with either GB or VX. The rockets are equipped with fuzes and bursters which contain explosives. Propellant is also built into the motor of the rocket. The rocket casing is made of aluminum. Some of the rockets have a leakage problem.

The rockets are individually packaged in fiberglass shipping tubes with metal end caps. Fifteen containers with rockets are packed on a wooded pallet.

3.2.2. Land Mines

Mines contain VX and explosive charges. The mines are packaged three to a steel drum. Mine activators and fuzes are packaged separately in the same drum. Twelve drums of mines are contained on a wooden pallet.

3.2.3. Projectiles and Mortars

The munitions stockpile contains 105-mm projectiles with GB or mustard, 155-mm projectiles with GB, VX, or mustard, 8-in. projectiles with GB or VX, and 4.2-in. mortar projectiles with mustard. Some 105-mm projectiles are stored as complete rounds containing fuze, burster with explosive, cartridge case and propellant, while others are stored without bursters, fuzes and propellant. Mortars are stored with fuzes, bursters, and propellants. Projectiles (155-mm and 8-in.) are also stored with and without bursters. For this study, it was assumed that fuzes and propellants have been removed from the 4.2-in. mortars and 105-mm cartridges.

The 105-mm projectiles are packed 24-projectiles to a pallet, and the 4.2-in. mortar projectiles are packed 48-projectiles to a pallet.

155-mm and 8-in. projectiles are packaged eight and six projectiles on a wooden pallet, respectively.

3.2.4. Bombs

There are three types of bombs, all containing GB agent. These are the MC-1, a 750-lb bomb, the MK-94, a 500-lb bomb, and the MK-116 ("weteye"), a 525-lb bomb. The 525-lb bomb is designed to release an aerosol spray of agent on detonation. The bombs are stored without explosives. The MC-1 bombs are packaged two to a wooden pallet and the others in individual metal shipping containers.

3.2.5. Spray Tanks

Spray tanks contain VX agent. They are designed for releasing chemical agent from slow-traveling, low-flying aircraft. The spray tanks are stored in a metal overpack container.

3.2.6. Bulk Agent

All three types of agent are stored in bulk as liquid in standard one-ton steel containers (called ton containers). Ton containers are not palletized.

Ton containers are the only items stored at the Aberdeen Proving Ground (APG) and Newport Army Ammunition Plant (NAAP). The ton containers at APG contain mustard (HD), while NAAP has VX-filled ton containers. The Anniston Army Depot (ANAD) has filled ton containers. Pine Bluff Arsenal (PBA) has mustard-filled ton containers. Tooele Army Depot (TEAD) has all types of bulk agent in storage. Umatilla Depot Activity (UMDA) has mustard-filled ton containers.

4. INITIATING EVENTS

This section describes the approaches used to identify and select initiating events and to assess or present their occurrence frequencies As described in Section 2, initiating events are single occurrences or individual malfunctions that either directly cause the release of chemical agents or start a sequence of events that could lead to a release. They are classified as external events when caused by natural phenomena (e.g., earthquakes) or man-made interferences (e.g., aircraft crashes) from outside the demilitarization cycle. They are classified as internal events when caused by human error or equipment failure within the demilitarization process. Section 4.1 describes the logic used for selection of the initiating events. Section 4.2 discusses the generic considerations in specifying the initiating event frequency units (i.e., per unit time or per operation). The application of the generic frequency estimates to specific accident scenarios and locations is discussed in the sections dealing with accident logic model development, Sections 5 through 8.

4.1. INITIATING EVENT IDENTIFICATION AND SELECTION

This study used a multifaceted approach for identifying potential initiating events, screening out those which (based on conservative scoping) should not affect the overall risk and selecting those events warranting further analysis. The approach consisted of:

1. Developing a master logic diagram (MLD), a logic tool described in the PRA Procedures Guide (Ref. 4-1) for systematically examining potential modes of release, pathways for release. barriers against release, and mitigating safety functions together with root causes (initiators) of release.

2. Cross-referencing results from item 1 with a list of accident scenarios from safety-related studies on the chemical weapons disposal program, compiled by MITRE Corporation in Refs. 4-2 and 4-3.

3. Applying previous munitions risk study experience in Refs. 4-4 through 4-12 (the results of these studies are described in Section 1.1).

4. Peer review by the Army and independent consultants during the early and draft report phases of this study.

Two criteria were used to screen accident scenarios: (1) accidents with extremely low frequency (below 10^{-10} per year) were eliminated from further analysis, and (2) those with low consequences (amount of agent release below 0.3 lb for GB, 14 lb for H or 0.4 lb for VX) were also screened. Events with frequencies below the cutoff have little meaning from a practical standpoint since the expected times between events is measured on a cosmic scale rather than on a scale of human history. The consequence criteria pertains to the minimum release levels that would produce acute human fatalities 0.5 km from the incident, based on environmental impact calculations performed by MITRE (Refs. 4-2 and 4-3).

For bookkeeping purposes, a coding system is used in this report to identify, organize and refer to accident sequences. Not all accident sequences were encoded; those that could be screened out early because of simple conservative scoping analysis bear no coding. Conversely, many sequences that were screened after detailed analysis retain their coding but may not be in the final lists of results. However, Appendix A contains a record of all encoded sequences.

Table 4-1 shows the coding scheme followed for identification of accident sequences. The coding system is based on that used in

TABLE 4-1
ACCIDENT SEQUENCE CODING SCHEME

The Accident Scenario Identification is an 8-Character Code for the Form: XXYZWnnn as Defined Below.

Activity (XX)	Munition Type (Y)	Agent Type (Z)
SL: Storage, long term	R: Rockets	V: VX
SH: Storage, handling for surveillance and maintenance	D: Mortars	
	C: Cartridges	G: GB
	P: Projectiles	H: HD/HT/H
	M: Mines	A: All to which a munition category applies
	B: Bombs	
	K: Ton containers	
	S: Spray tanks	
	A: All	

Release Mode (W)	Sequence No. (nnn)
S: Spill or leak	001, 002, 003, ... 999
C: Complex (e.g., detonation with fire)	
F: Fire only	

[a] For air transport, AA is for C-5 and AB is for C-141 aircraft. For ship transport, BI covers barge events; LI, LC, and LS are for LASH events in intercoastal, coastal and high-sea waters, respectively.

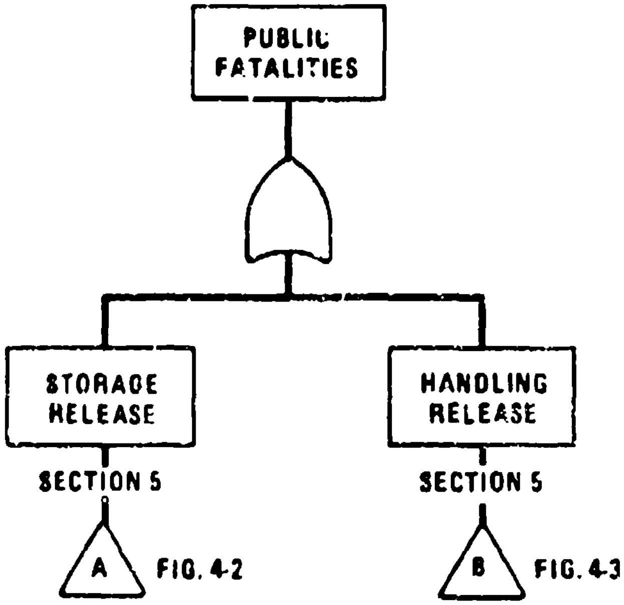
Refs. 4-2 and 4-3. The first two letters identify the demilitarization phase (SL for storage, long term, SH for special handling activities). The first two letters together with the sequence number at the end uniquely identify an accident sequence of events. The middle letters identify the munition/agent type combinations and the release mode. Throughout this report, either the entire coding is used or sequences are referred to by the first two letters and the sequence number.

The MLD developed for the risk study event identification is shown in Figs. 4-1 through 4-3. Following the PRA Procedures Guide (Ref. 4-1), the top level logic (Fig. 4-1, level 1) pertains to the public impact, in this case, fatalities due to exposure to chemical releases throughout the long-term storage.

Figure 4-2 shows MLD level 2 (release mode or pathway) and subsequent levels (barriers to release, safety functions mitigation/failure and, finally, event initiators) for storage. It shows three modes for release. One is leakage of agent from corroded munitions, such as leakage of a ton container stored in open areas. Another is inadvertent rupture of a munition during maintenance. The third is a disruptive influence due to an external event.

Subsequent levels are developed considering the types of disruptive events that can occur, taking into account information on the potential failure modes of the munitions (puncture, detonation, fire, etc.), given that the event occurs. For illustration, some sequences analyzed in Section 5 are noted under the initiating event boxes. Table 4-2 summarizes the initiating event families for storage selected for analysis.

Figure 4-3 shows the MLD levels 2 and lower for handling operations. There are modes of release: impact rupture due to handling accidents (drops and forklift collisions), and forklift tine puncture. Note that external events are not included here; external events for storage and transport consider the entire munitions inventory available



NOTE: This risk analysis identifies releases of sufficient magnitude to cause acute public fatalities. Lower level releases would result in exposures but are not considered.

Fig. 4-1. Master logic diagram - level 1 (public impact)

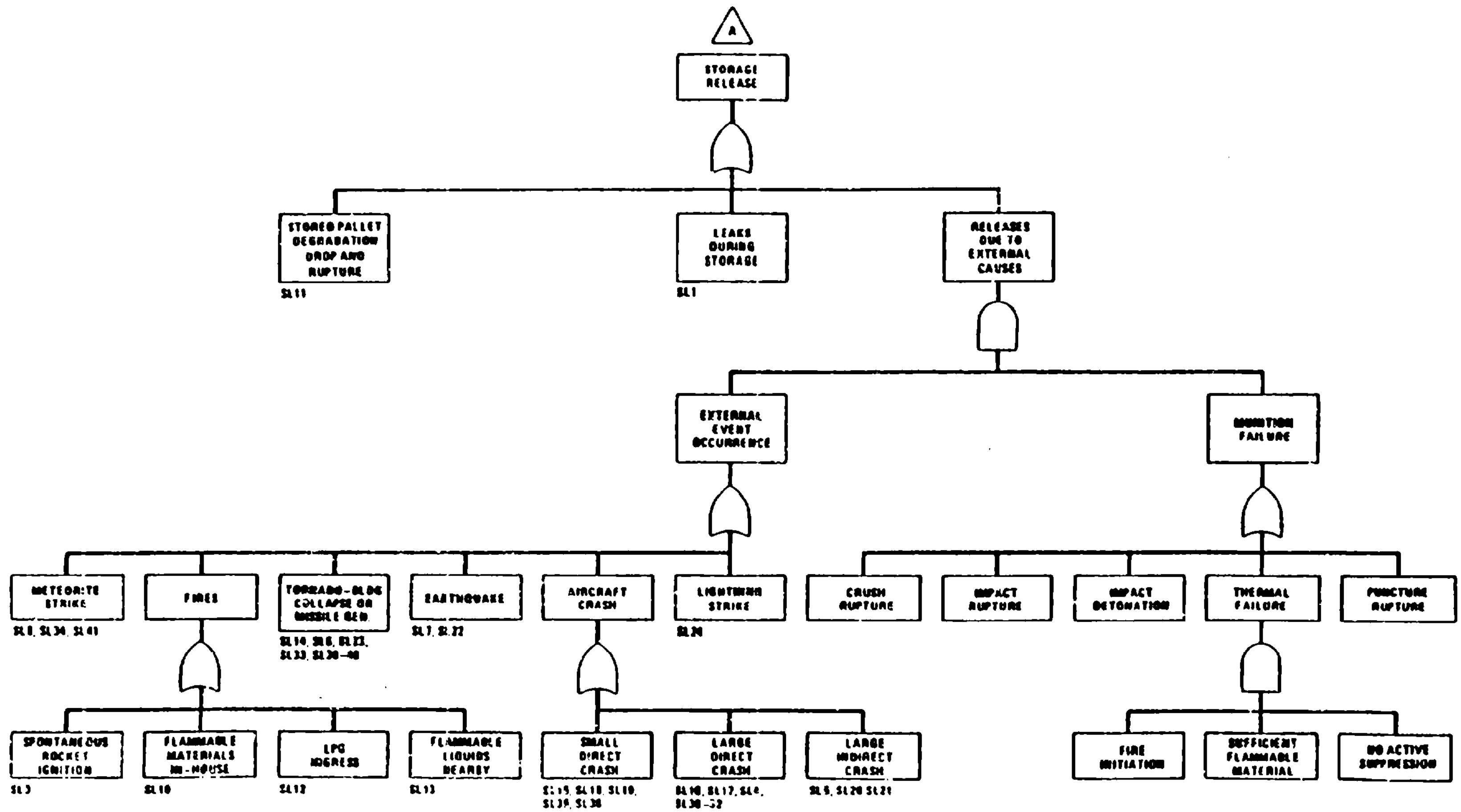


Fig. 4-2. Master logic diagram - levels 2 (release pathway) and lower (barriers, safety functions, and initiators). Part A - storage release

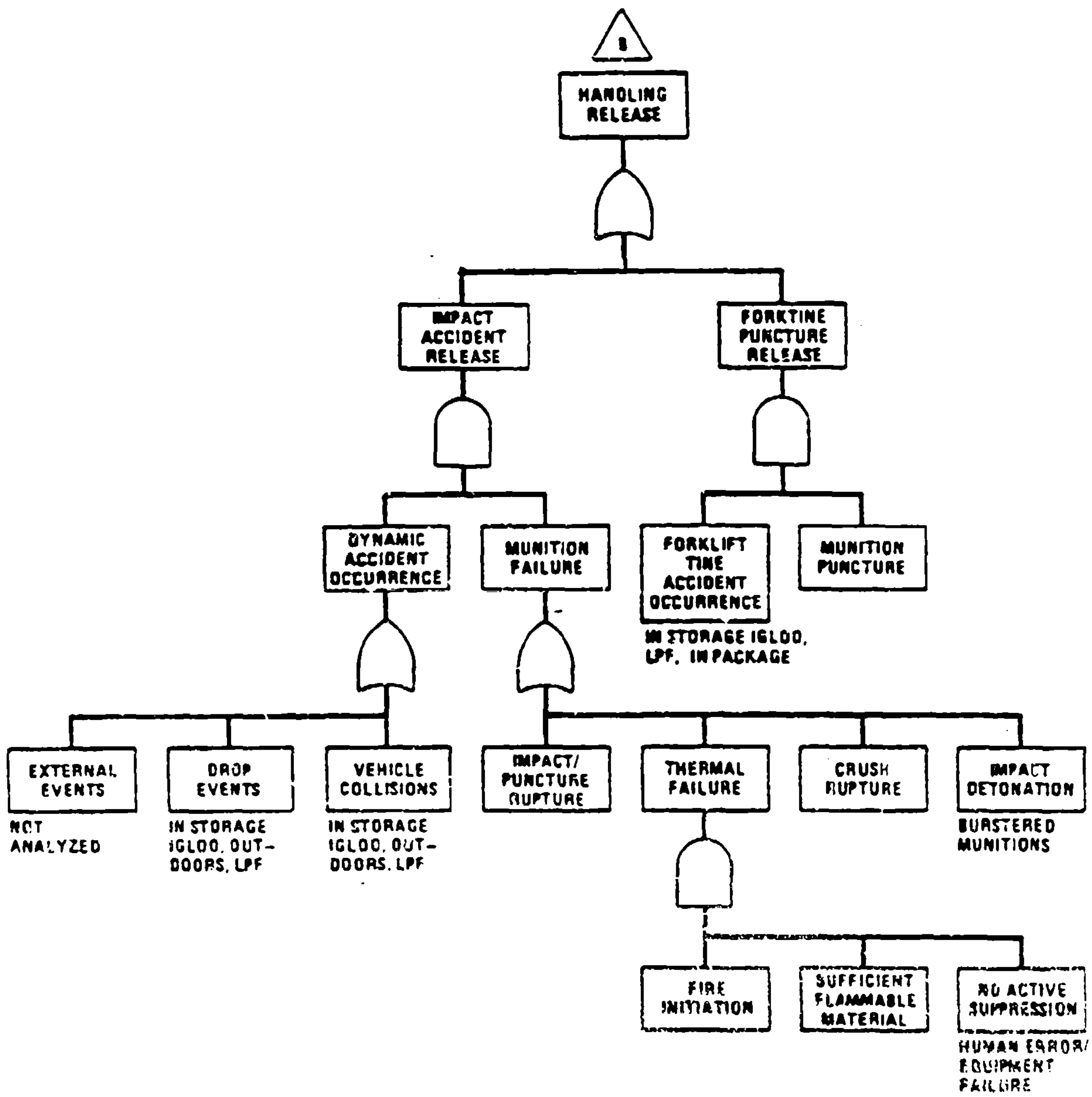


Fig. 4-3. Master logic diagram - levels 2 (release pathway) and lower (barriers, safety functions, and initiators). Part B - storage release

TABLE 4-2
INITIATING EVENT FAMILIES FOR STORAGE

INTERNAL EVENTS

1. Munition drop

   a. During leaker isolation
   b. Due to pallet degradation

2. Forklift tine puncture during leaker isolation

3. Leak between inspections

EXTERNAL EVENTS[a]

1. Fires due to:

   a. Spontaneous ignition of a rocket
   b. Flammable materials in an igloo or warehouse
   c. LPG ingress into an igloo or warehouse
   d. Flammable liquids near a warehouse at NAAP

2. Meteorite strikes an igloo or warehouse

3. Tornado collapses a building or generates a missile

4. Aircraft crash due to:

   a. Small aircraft (direct)
   b. Large aircraft (direct)
   c. Large aircraft (indirect)

5. Earthquake

6. Lightning strikes outdoor storage

[a]Note: External initiators, floods, and fires are shown in Section 5 to be low risk contributors.

regardless of whether handling operations are in progress. The subsequent level initiating events consider the location where the event occurs, since different barriers for release are involved (e.g., if the event occurs indoors or in an open area). Essentially, there are 18 (3 x 3 x 2 matrix) handling accident combinations. These are related to the number of munitions involved (a single munition, pallet, or container); the release mechanism (drop, forklift collision, or forklift tine puncture); and whether the release occurs inside or outdoors. Table 4-3 summarizes the families or handling initiating events selected for analysis.

TABLE 4-3
INITIATING EVENT FAMILIES FOR HANDLING

1. Number of munitions involved

   a. Bare munition
   b. Pallet
   c. Container

2. Agent release mechanism

   a. Drop
   b. Forklift tine puncture

3. Release location

   a. Inside a storage area or maintenance facility
   b. Outdoors

4.2. INITIATING EVENT FREQUENCIES

4.2.1. External Events

This section presents the site-specific frequencies of external initiating events considered in this study. Table 4-4 summarizes the results for occurrences at each of the eight CONUS sites. The bases for these results are discussed in the following subsections.

4.2.1.1. Earthquakes. The frequency at which a major earthquake occurs at a specific site varies significantly throughout the United States. In an attempt to quantify the seismic risk associated with a particular site, the Seismology Committee of the Structural Engineers Association of California (SEAOC) has divided the United States into five seismic zones. Maps of these seismic zones are presented in the Uniform Building Code (Ref. 4-13) and in Army TM 5-809-10 (Ref. 4-14). Figure 4-4 presents the seismic zone map from TM 5-809-10, and Table 4-5 presents the seismic zones indicated for each of the storage sites. The probability of seismic damage in each of the zones is defined in Ref. 4-13 as follows:

Zone 0 - None	Zone 3 - Major
Zone 1 - Minor	Zone 4 - Great
Zone 2 - Moderate	

The determination of a seismic zone on a site is based on the history of past earthquakes and the proximity of known faults. Appendix D presents listings of the earthquakes that have occurred in the vicinity of each of the storage sites. The magnitudes of the earthquakes are expressed as Modified Mercalli Intensities (MMI). Table 4-5 presents a summary of the maximum earthquake occurring in the vicinity of each of the storage sites. The maximum earthquake recorded at any of the eight storage sites is an MMI VIII.

TABLE 4-4
SITE SPECIFIC FREQUENCIES OF EXTERNAL INITIATING EVENTS

	APG	ANAD	LBAD	NAAP	PBA	PUDA	TEAD	UMDA
Large aircraft crash (events/yr-mi^2)	$5.3x10^{-7}$	$7.9x10^{-6}$	$4.5x10^{-6}$	$4.6x10^{-6}$	$1.5x10^{-6}$	$5.9x10^{-5}$	$3.6x10^{-7}$	$1.5x10^{-5}$
Small aircraft crash (events/yr-mi^2)	$7.8x10^{-3}$	$1.2x10^{-5}$	$1.8x10^{-7}$	$2.3x10^{-5}$	$1.1x10^{-4}$	$1.0x10^{-4}$	$1.5x10^{-5}$	$1.2x10^{-5}$
Meteorite (>1.0 lb) strikes (events/yr-ft^2)	$6.4x10^{-13}$	$6.4x10^{-13}$	$6.4x10^{-13}$	$6.4x10^{-13}$	$6.4x10^{-13}$	$6.4x10^{-13}$	$6.4x10^{-13}$	$6.4x10^{-13}$
Lightning (events/yr-mi^2)	7.8	23.3	23.3	12.9	28.5	10.4	7.8	5.2
Earthquakes (events/yr)								
- 0.15 g	$1.5x10^{-4}$	$1.5x10^{-4}$	$1.5x10^{-4}$	$7.5x10^{-4}$	$1.5x10^{-4}$	$1.5x10^{-4}$	$4.0x10^{-3}$	$1.5x10^{-4}$
- 0.2 g	$7.0x10^{-5}$	$7.0x10^{-5}$	$7.0x10^{-5}$	$3.6x10^{-4}$	$7.0x10^{-5}$	$7.0x10^{-5}$	$2.0x10^{-3}$	$7.0x10^{-5}$
- 0.25 g	$4.0x10^{-5}$	$4.0x10^{-5}$	$4.0x10^{-5}$	$2.3x10^{-4}$	$4.0x10^{-5}$	$4.0x10^{-5}$	$1.0x10^{-3}$	$4.0x10^{-5}$
- 0.3 g	$2.5x10^{-5}$	$2.5x10^{-5}$	$2.5x10^{-5}$	$1.3x10^{-4}$	$2.5x10^{-5}$	$2.5x10^{-5}$	$7.0x10^{-4}$	$2.5x10^{-5}$
- 0.4 g	$1.2x10^{-5}$	$1.2x10^{-5}$	$1.2x10^{-5}$	$5.0x10^{-5}$	$1.2x10^{-5}$	$1.2x10^{-5}$	$2.6x10^{-4}$	$1.2x10^{-5}$
- 0.5 g	$6.0x10^{-6}$	$6.0x10^{-6}$	$6.0x10^{-6}$	$2.0x10^{-5}$	$6.0x10^{-6}$	$6.0x10^{-6}$	$1.0x10^{-4}$	$6.0x10^{-6}$
- 0.6 g	$3.5x10^{-6}$	$3.5x10^{-6}$	$3.5x10^{-6}$	$1.0x10^{-5}$	$3.5x10^{-6}$	$3.5x10^{-6}$	$4.5x10^{-5}$	$3.5x10^{-6}$
- 0.7 g	$2.5x10^{-6}$	$2.5x10^{-6}$	$2.5x10^{-6}$	$7.0x10^{-6}$	$2.5x10^{-6}$	$2.5x10^{-6}$	$2.0x10^{-5}$	$2.5x10^{-6}$
Tornadoes (events/yr)								
- 100 mph wind speed	---	---	---	---	---	---	$1.0x10^{-5}$	$1.0x10^{-5}$
- 140 mph wind speed	---	---	---	---	---	---	$1.0x10^{-6}$	$1.0x10^{-6}$
- 150 mph wind speed	$1.0x10^{-5}$	---	---	---	---	$1.0x10^{-5}$	---	---
- 180 mph wind speed	---	---	---	---	---	---	$1.0x10^{-7}$	$1.0x10^{-7}$
- 200 mph wind speed	$1.0x10^{-6}$	$1.0x10^{-5}$	$1.0x10^{-5}$	$1.0x10^{-5}$	$1.0x10^{-5}$	$1.0x10^{-6}$	---	---
- 250 mph wind speed	$1.0x10^{-7}$	---	---	---	---	$1.0x10^{-7}$	---	---
- 260 mph wind speed	---	$1.0x10^{-6}$	$1.0x10^{-6}$	$1.0x10^{-6}$	$1.0x10^{-6}$	---	---	---
- 320 mph wind speed	---	$1.0x10^{-7}$	$1.0x10^{-7}$	$1.0x10^{-7}$	$1.0x10^{-7}$	---	---	---

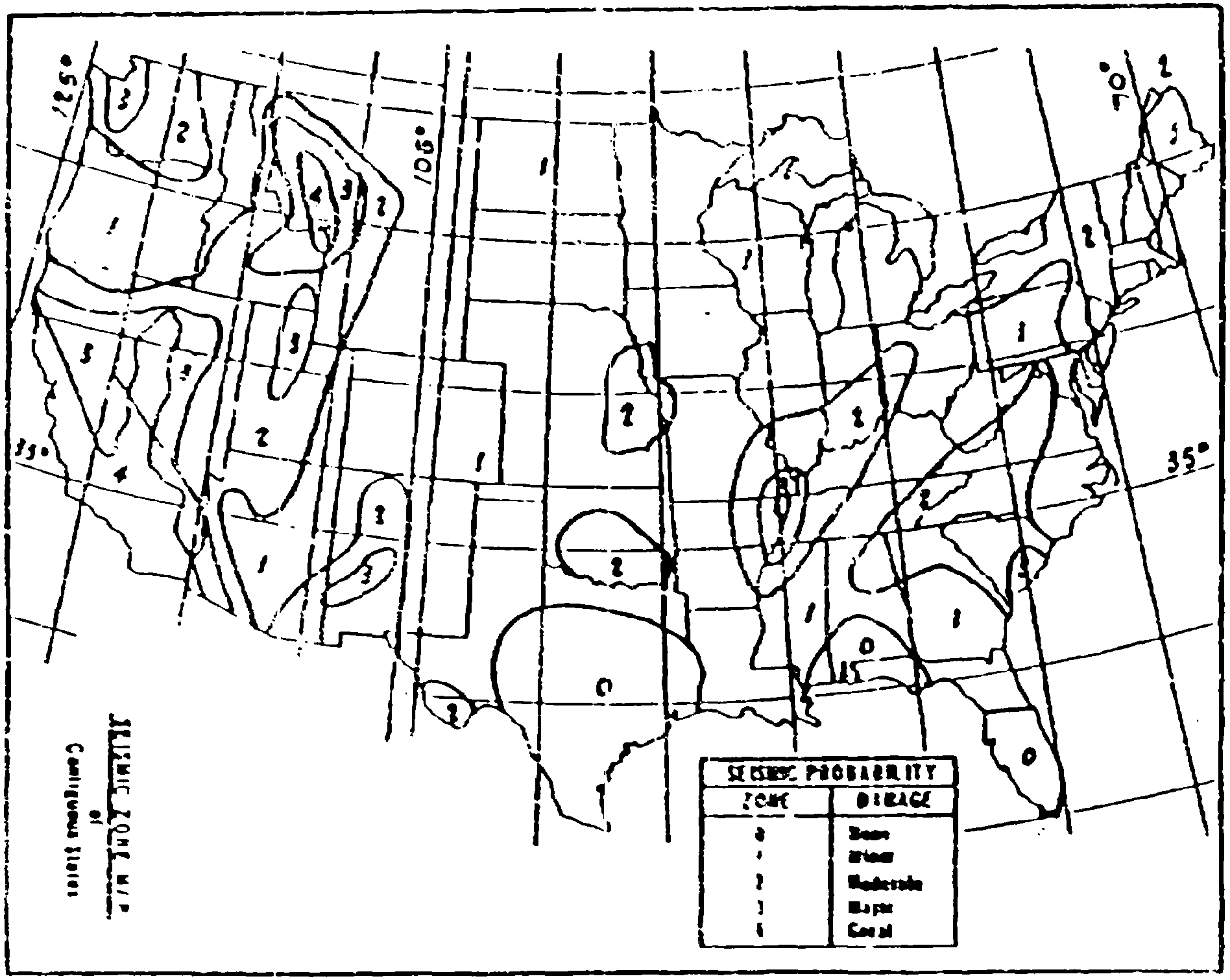


Fig. 4-4. Seismic zone map for the contiguous United States

TABLE 4-5
MAXIMUM MODIFIED MERCALLI INTENSITIES (MMI) IN THE VICINITY OF EACH SITE

Site	Seismic Zone	MM Intensity	No. of Occurrences
Aberdeen Proving Ground (APG)	1	VII	1
Pine Bluff Arsenal (PBA)	1	VI	3
Pueblo Depot Activity (PUDA)	1	VI	1
Umatilla Depot Activity (UMDA)	1	VII	1
Anniston Army Depot (ANAD)	2	VII	1
Newport Army Ammunition Plant (NAAP)	2	VII	1
Lexington-Blue Grass Army Depot (LBAD)	2	VII	1
Tooele Army Depot (TEAD)	3	VIII	2

Currently the Applied Technology Council, which is associated with the SEAOC, is developing new seismic regulations for buildings (Ref. 4-15). When this work is completed, it is expected to be the basis for future federal, state, and local building codes. Part of this work was the development of a seismic risk map that divides the United States into seven seismic map areas similar to the five seismic zones used in Refs. 4-13 and 4-14. The seismic risk is approximately constant throughout a seismic map area.

Figure 4-5 (from Ref. 4-15) presents a set of curves that can be used to estimate the probabilities of earthquakes of various g-levels occurring within a particular seismic map area. The dashed portions of the curves indicate possible extrapolations to larger and smaller annual probabilities.

Table 4-6 identifies the seismic map areas for each of the CONUS sites and tabulates the annual frequencies of earthquakes of various g-levels being exceeded at the storage sites. The data in Table 4-6 were obtained from Fig. 4-5. Straight-line, logarithmic extrapolation was used to extrapolate to accelerations beyond the curves shown in Fig. 4-5. This method of extrapolation is believed to produce conservative estimates of the probabilities.

4.2.1.2. Wind Hazards. Methods for estimating the frequency and intensity of extreme winds can be found in ANSI/ANS-2.3-1983 (Ref. 4-16). The discussion which follows is largely based on the referenced national standard.

4.2.1.2.1. Tornadoes. A tornado is a violently rotating column of air whose circulation reaches the ground. The velocity of tornadic winds can exceed 300 mph. The path of a tornado can be more than a mile in width, but generally ranges from 0.125 to 0.75-mile wide. The path width is defined as the tornado diameter corresponding to a 75 mph wind velocity. The path of a tornado is seldom more than 10 miles long,

TABLE 4-6
ANNUAL RISK OF EARTHQUAKES

Site	Map Area	Acceleration (g-level)							
		0.15	0.20	0.25	0.3	0.4	0.5	0.6	0.7
TEAD	5	4.0E-3	2.0E-3	1.0E-3	7.0E-4	2.6E-4	1.0E-4	4.5E-5	2.0E-5
NAAP	3	7.5E-4	3.6E-4	2.3E-4	1.3E-4	5.0E-5	2.0E-5	1.0E-5	7.0E-6
APG, ANAD, LBAD, PBA, UMDA, PUDA	2	1.5E-4	7.0E-5	4.0E-5	2.5E-5	1.2E-5	6.0E-6	3.5E-6	2.5E-6

Data obtained from Fig. 4-11.

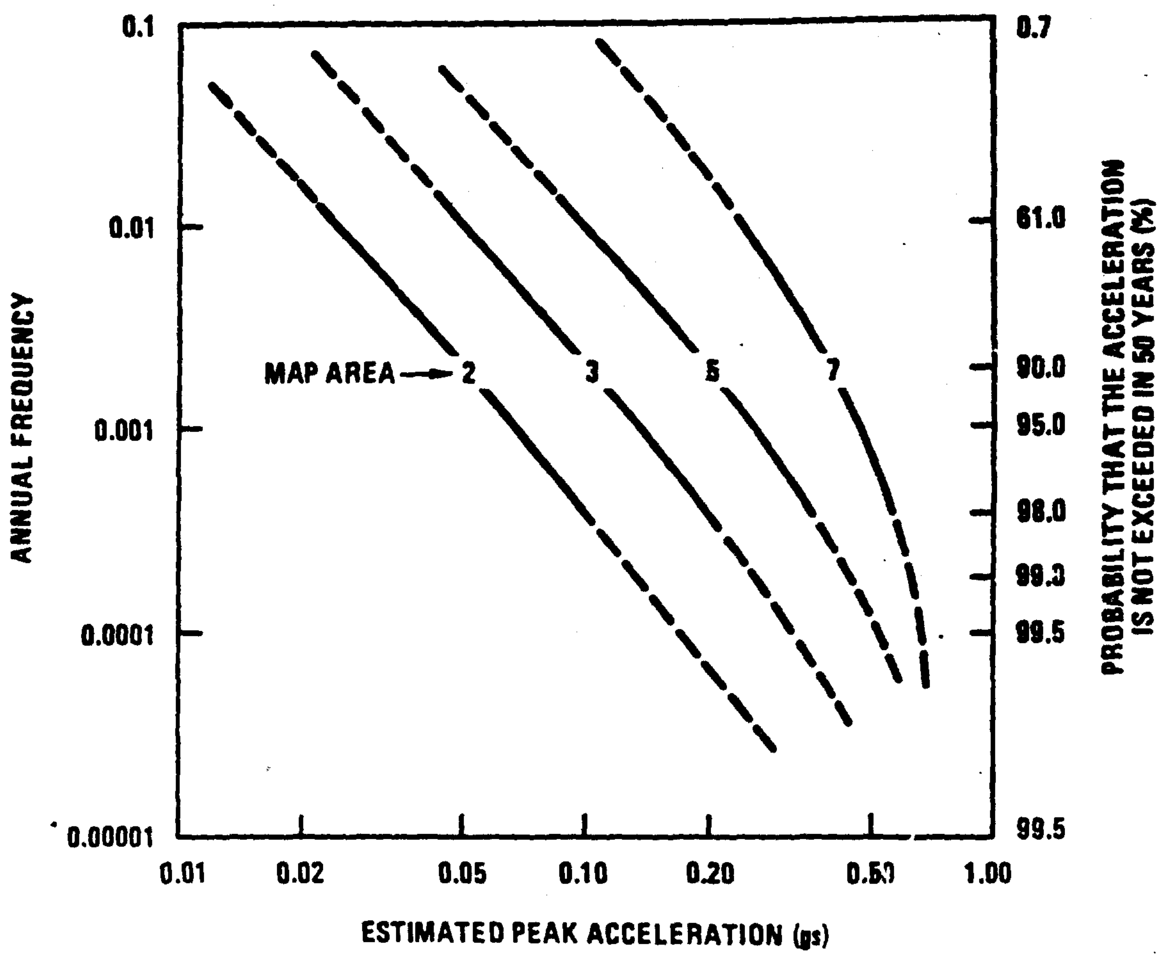


Fig. 4-5. Annual frequency of exceeding various effective peak accelerations for selected map areas defined by the Applied Technology Council (Ref. 4-15)

although extreme cases are on record where the storm path extended more than 200 miles.

Meteorological and topographic conditions, which vary significantly from site to site, influence the frequency of occurrence and intensity of tornadoes. Reference 4-16 presents three regionalized maps of tornadic wind speeds corresponding to return frequencies of 1×10^{-7}, 1×10^{-6}, and 1×10^{-5} per year. These maps (Figs. 4-6 through 4-8) are expected to bound the tornado intensity probabilities at the various sites (Ref. 4-16). A tabulation of maximum tornado wind speed and occurrence frequency for each of the storage sites based on these figures is presented in Table 4-7.

4.2.1.2.2. Tornado-Generated Missiles. One of the characteristics of a tornado is its capability to generate missiles from objects lying within the strike area and from nearby structural debris. The selection of tornado-generated missiles is dependent on the intensity of the tornado, the number of potential missiles present, their position relative to the tornado path, and the physical properties of the missiles. Reference 4-17 presents a spectrum of actual wind-generated missiles. Characteristics of these missiles are listed in Table 4-8, and expected windborne missile velocities are listed in Table 4-9.

4.2.1.2.3. Other Extreme Winds. The approach used for the determination of extreme wind speed (other than tornado) including hurricane winds is the method suggested by Science Applications International Corporation (SAIC) (Ref. 4-12) using a basic wind speed as defined in Ref. 4-16. A frequency of occurrence of 0.02 per year is associated with a basic wind speed of 70 mph. SAIC concluded that the basic wind speed was applicable to all of the sites that store M55 rockets. Lacking site-specific meteorological data, it is assumed that the basic wind speed is applicable to the other sites as well.

In order to estimate the frequency of recurrence of winds of velocity greater than the basic wind speed, but less than the tornado wind

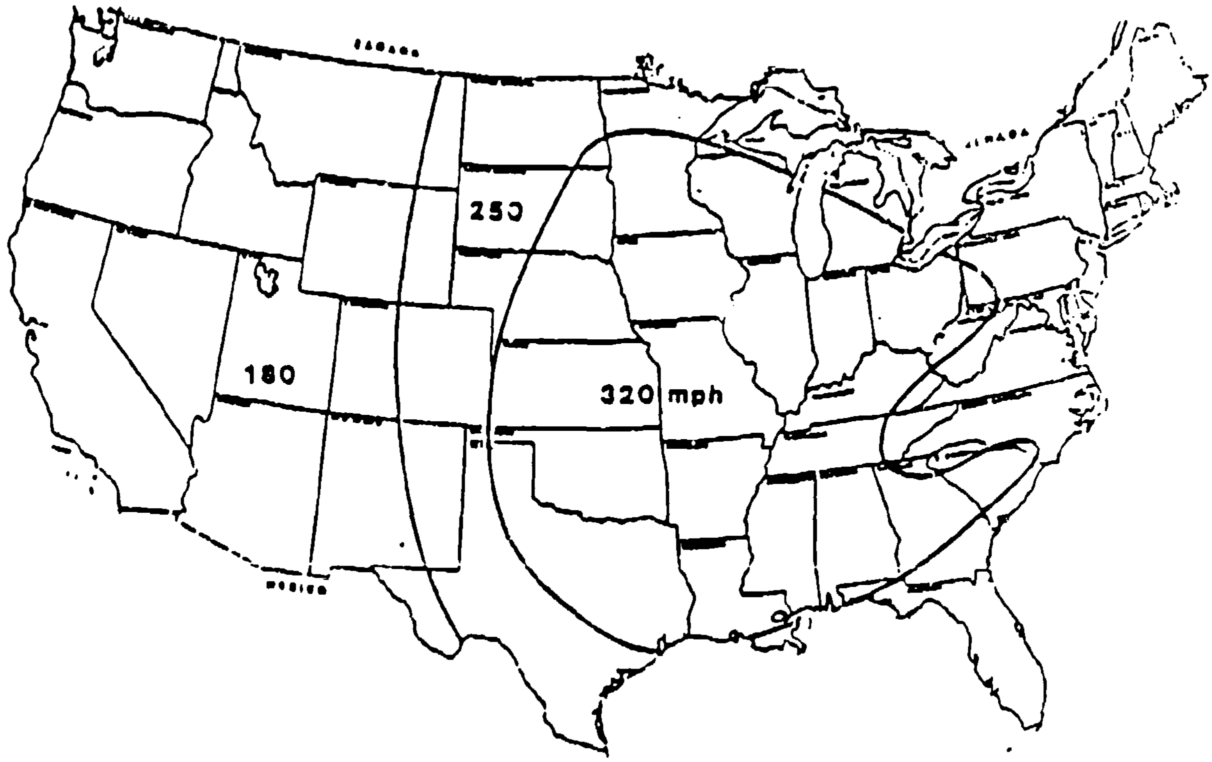


Fig. 4-6. Tornadic winds corresponding to a probability of 1×10^{-7} per year

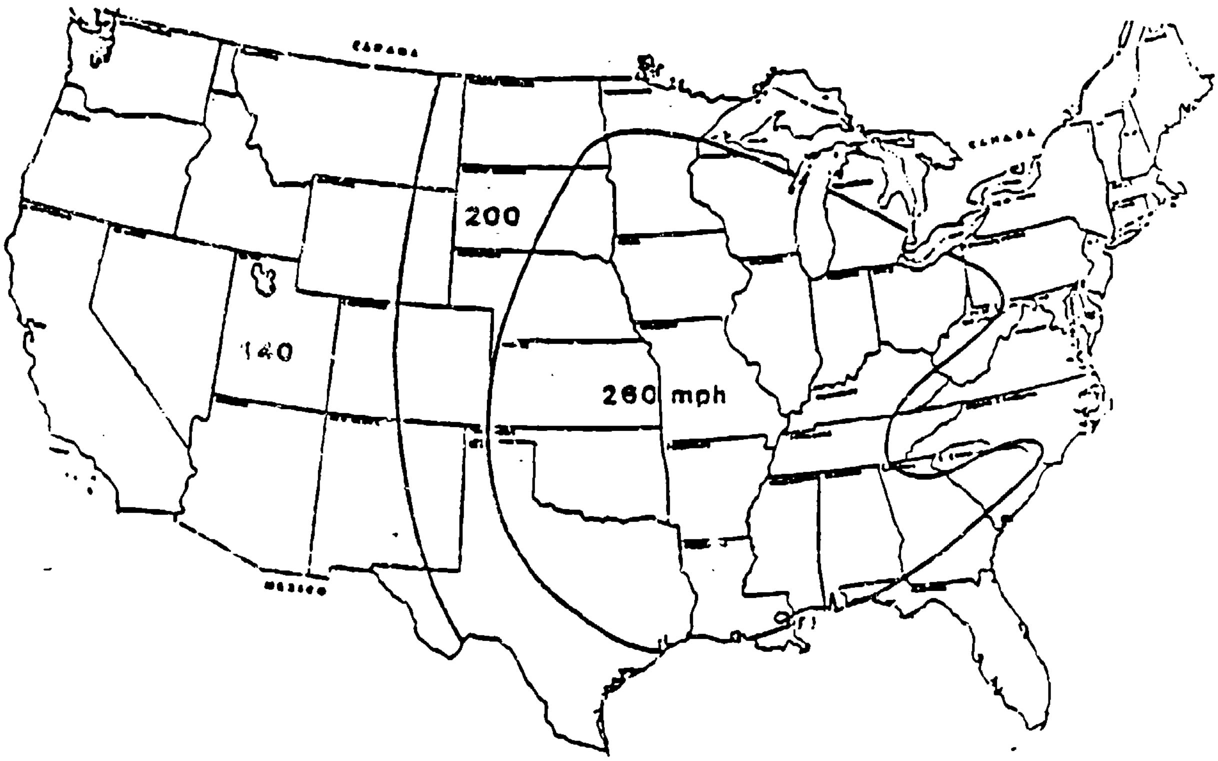


Fig. 4-7. Tornadic winds corresponding to a probability of 1×10^{-6} per year

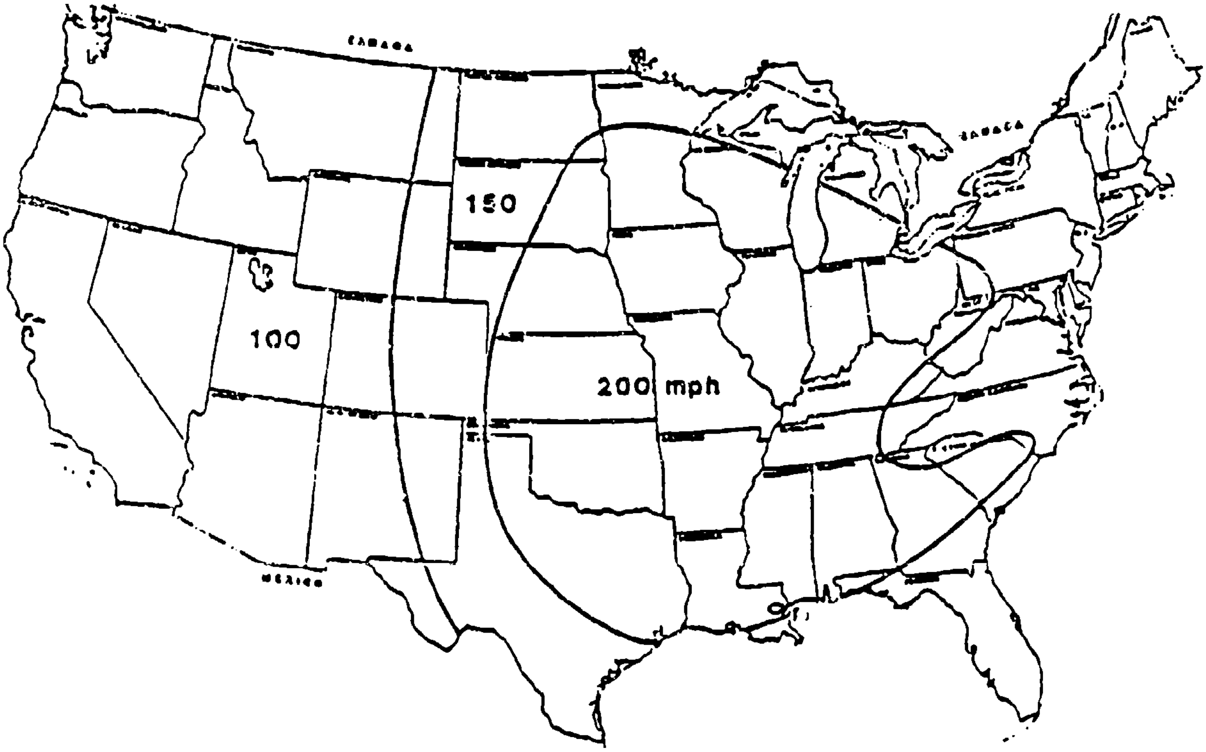


Fig. 4-8. Tornadic winds corresponding to a probability of 1×10^{-5} per year

TABLE 4-7
TORNADO WIND SPEEDS AND PROBABILITY OF RECURRENCE
FOR CHEMICAL STORAGE SITES

Size	Probability of Occurrence Per Year (Wind Speed (mph))		
	1×10^{-5}	1×10^{-6}	1×10^{-7}
ANAD (Anniston, Ala.)	200	260	320
LBAD (Lexington, Ky.)	200	260	320
UMDA (Umatilla, Oreg.)	100	140	180
PBA (Pine Bluff, Ark.)	200	260	320
TEAD (Tooele, Utah)	100	140	180
PUDA (Pueblo, Colo.)	150	200	250
NAAP (Newport, Ind.)	200	260	320
APG (Aberdeen, Md.)	150	200	250

TABLE 4-8
WIND-GENERATED MISSILE PARAMETERS[a]

Missile	Weight (lb)	Projected Area (ft^2)	Cross-Sectional Area (ft^2)
Timber plank 4 in. x 12 in. x 12 ft	139	11.50	0.29
3-in.-diam standard steel pipe x 10 ft	75.8	2.29	0.0155[b]
Utility pole 13.5-in.-diam x 35 ft	1490	39.4	0.99
Automobile	4000	100.0	20.0

[a] Source: Ref. 4-17.

[b] Value given is metal area. In penetration calculations the gross cross-sectional area may be used.

TABLE 4-9
WINDBORNE MISSILE VELOCITIES[a]

	Horizontal Missile Velocity[b] (mph)						Maximum Height (ft)
Design Wind Speed	100	150	200	250	300	350	
Timber plank	60	72	90	100	125	175	200
3-in.-diam standard pipe	40	50	65	85	110	140	100
Utility pole	(c)	(c)	(c)	80	100	130	30
Automobile	(c)	(c)	(c)	25	45	70	30

[a] Source: Ref. 4-17.

[b] Vertical velocities are taken as two-thirds the horizontal missile velocity. Horizontal and vertical velocities should not be combined vectorially.

[c] Missile will not be picked up or sustained by the wind; however, for this analysis, any initial missile velocity of 80 mph or less was assigned a wind velocity of 250 mph.

speed, the following approach was taken. The tornado strength and frequency data, and the basic wind strength and frequency data were plotted on a scale of log probability versus wind strength. The results are shown in Figs. 4-9 through 4-11 for the three tornado regions of the United States as given in Ref. 4-16. A conservative approach to interpolating between the available data points is the bilinear approximation shown by the solid lines in the figures. With these figures, the probability of a given wind velocity occurring at any of the chemical storage sites can be estimated.

4.2.1.3. Aircraft Operations. Much of the data in this section were taken from the SAIC report (Ref. 4-12) and NUREG-0800 (Ref. 4-18).

There are three major concerns in assessing potential hazards due to aircraft operations:

1. Proximity of aircraft operations to munitions areas.
2. The frequency of aircraft flights.
3. The characteristics of the aircraft traffic.

The proximity of aircraft operations to munitions activities is an important consideration in that approximately 50% of aircraft accidents that result in fatalities or destroy aircraft occur within 5 miles of airports (Ref. 4-12). Also, the close proximity of flight paths to munitions activities increases the likelihood of these areas receiving falling debris from aircraft accidents. The frequency of flight activity increases the possibility of damage to munitions by increasing the overall likelihood of an aircraft accident.

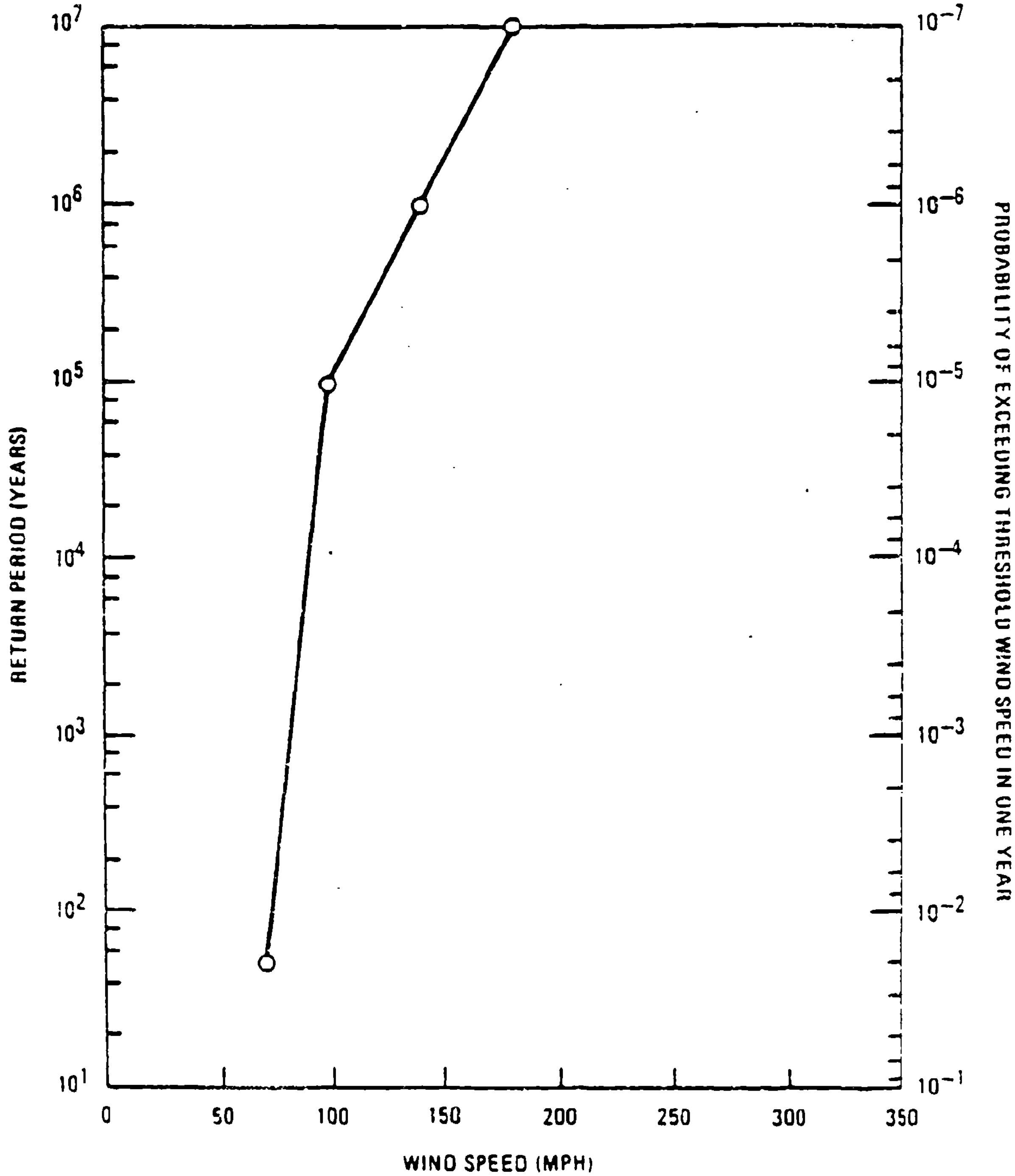


Fig. 4-9. Wind strength versus probability of recurrence, tornado Zone I (TEAD and UMDA sites)

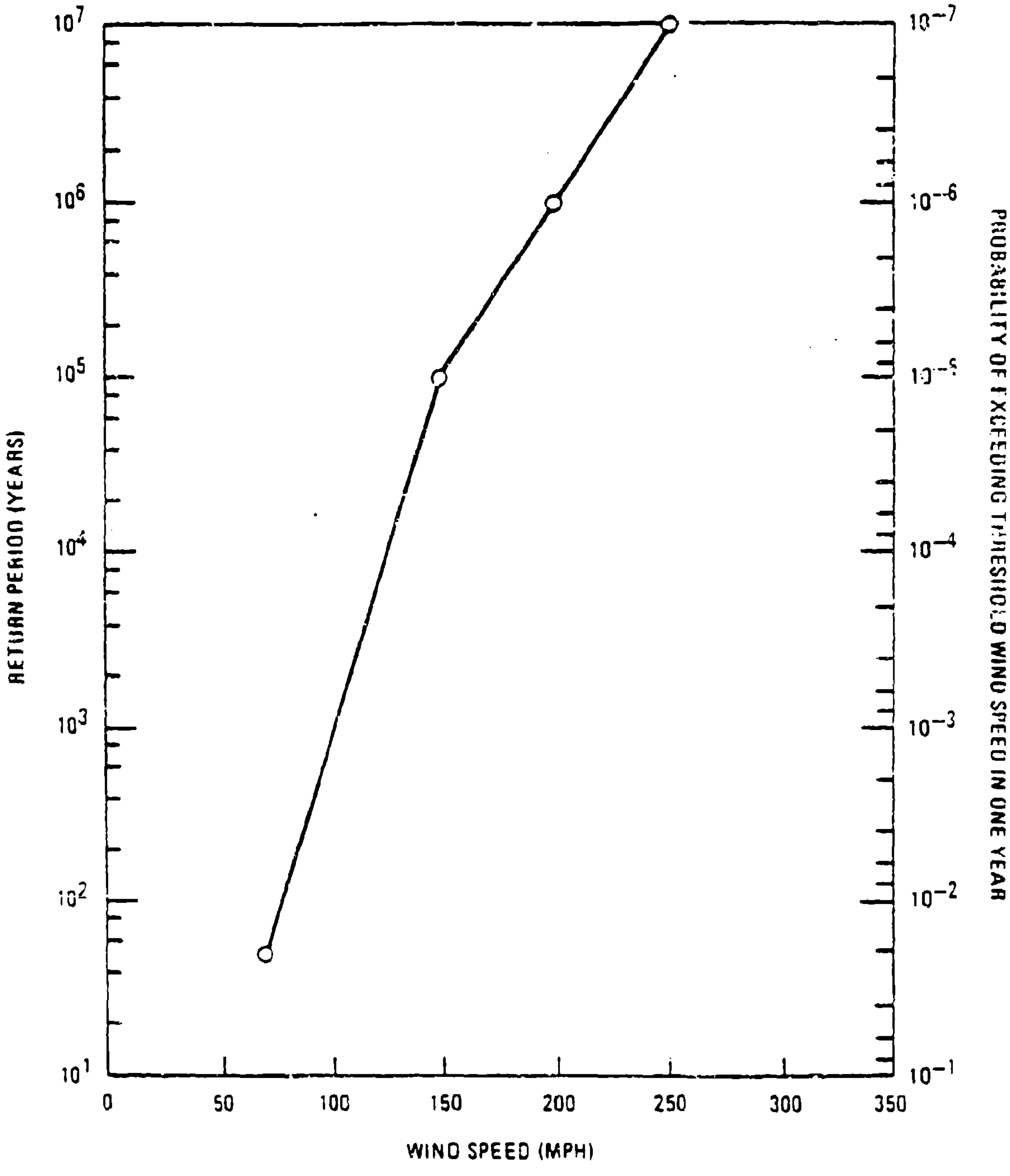


Fig. 4-10. Wind strength versus probability of recurrence, tornado Zone II (PUDA and APG sites)

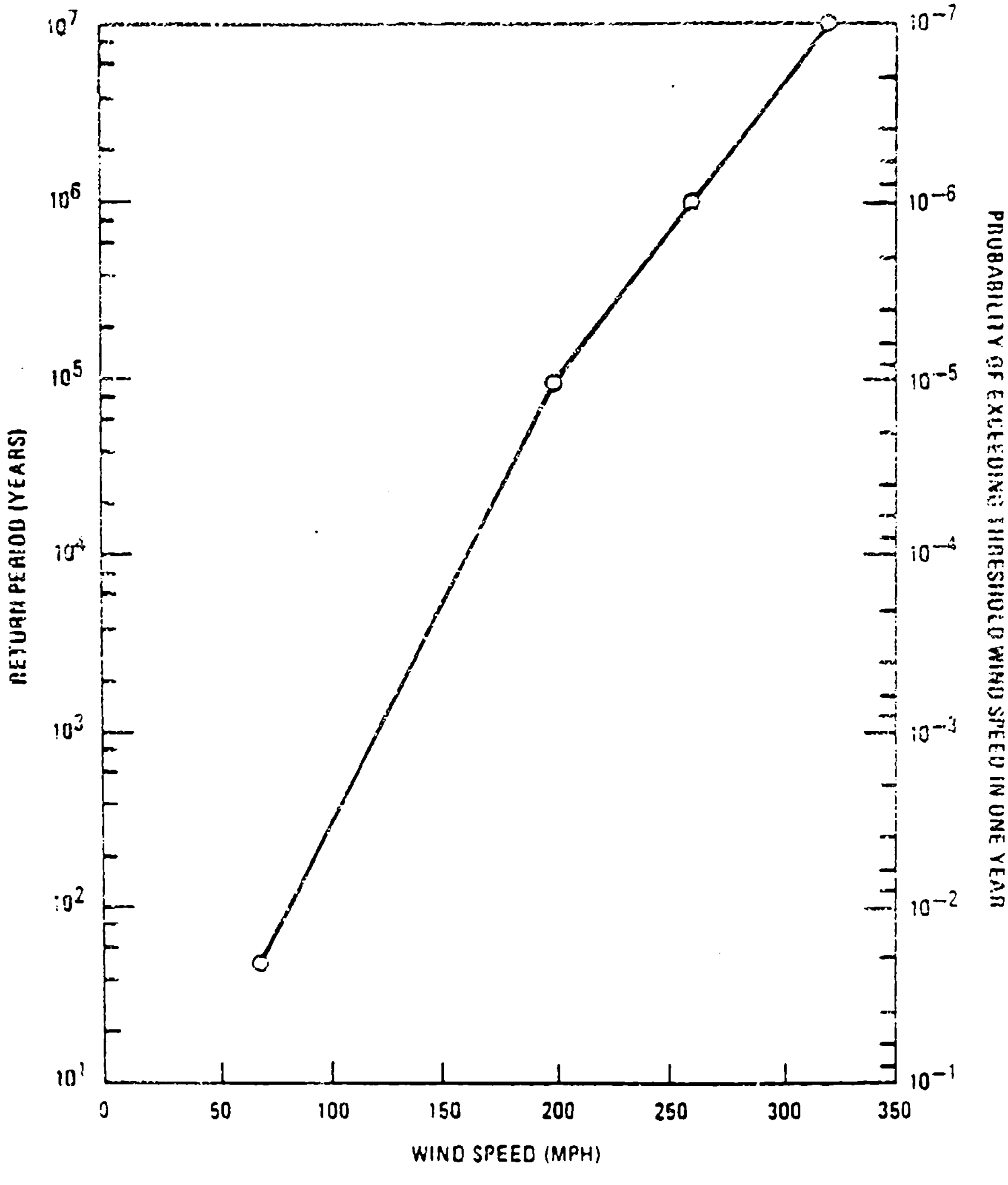


Fig. 4-11. Wind strength versus probability of recurrence, tornado Zone I (ANAD, LBAD, PGA, and NAAP sites)

Per the recommendations of NUREG-0800 (Ref. 4-18), the probability of an aircraft crash can be considered small if the distance to the site meets the following requirements:

1. The site-to-airport distance (D) is between 5 and 10 statute miles, and the projected annual number of flight operations is less than 500 D^2, or the site-to-airport distance is greater than 10 statute miles, and the projected annual number of operations is less than 1000 D^2.

2. The site is at least 5 statute miles from the edge of military training routes, including low-level training routes, except those associated with a usage greater than 1000 flights per year, or where activities may create an unusual stress situation.

3. The site is at least 2 statute miles beyond the nearest edge of a federal airway, holding pattern, or approach pattern.

The characteristics of an aircraft, such as its weight, number of engines, etc., are important in determining the energy of potential missiles generated in an aircraft accident, and depending on the structure they hit, the magnitude of the damage they may cause.

The frequency of an aircraft crashing while in an airway can be computed as follows (Ref. 4-18):

$$P_{FA} = C \times N \times A/W \quad , \qquad (4\text{-}1)$$

where C = inflight crash rate per mile for aircraft using airway,

W = width of airway (plus twice the distance from the airway edge to the site when the site is outside the airway) in miles,

A = effective area of facility in square miles,

N = number of flights per year along the airway.

For commercial aircraft, a value for C of 1×10^{-10} has been used (Ref. 4-12). For military aircraft, C is estimated to be five times the value for commercial flights (Ref. 4-12). For general aviation, C was estimated to be the same as for military aircraft.

The frequency of an aircraft crashing in the vicinity of an airport or heliport can be computed as follows (Ref. 4-18):

$$P_A = \sum_{i=1}^{L} \sum_{j=1}^{M} C_j N_{ij} A_j \quad , \qquad (4\text{-}2)$$

where L = number of flight trajectories affecting the target,

M = number of different flights using the airport,

C_j = probability per square mile of a crash per aircraft movement for j^{th} aircraft,

N_{ij} = number per year of movements by the j^{th} aircraft,

A_j = effective target area in square miles for the j^{th} aircraft.

The values for C_j which were used in the analysis are listed in Table 4-10. The total crash probability is the sum of P_{FA} and P_A.

The Federal Aviation Administration (FAA) does not monitor the number of certain types of aircraft that fly the high and low altitude airways. Consequently, the air traffic was estimated. Since air traffic is not the same on all airways, the airways are divided into five categories with regard to air traffic: very low, low, medium, high, and very high. Table 4-11 presents estimates of the air traffic on each of these airways. Each airway was assigned to one of these categories based on the traffic expected between the cities that the airway connects. If there are no low altitude airways near a site, it is assumed that the air traffic over the site is at least equal to that for a very low air traffic airway.

TABLE 4-10
AIRCRAFT CRASH PROBABILITIES NEAR AIRPORTS

Distance From End of Runway	Probability (x 10^8) of a Fatal Crash per Square Mile per Aircraft Movement			
	Commercial	General Aviation	Military	Helicopters
0-1	16.7	84	7.0	168
1-2	4.0	15	1.7	30
2-3	0.96	6.2	0.72	12
3-4	0.68	3.8	0.37	7.6
4-5	0.27	1.2	0.30	2.4
5-6	0.14	0.70	0.14	1.4
6-7	0.14	0.70	0.14	1.4
7-8	0.14	0.70	0.14	1.4
8-9	0.14	0.70	0.14	1.4
9-10	0.12	0.60	0.12	1.2

TABLE 4-11
ASSUMED DISTRIBUTION OF AIR TRAFFIC[a]

Aircraft	Very Low	Low	Medium	High	Very High
			High Altitude Jet Routes		
Large commercial	1,000	2,000	5,000	10,000	20,000
Large military	500	1,000	2,500	5,000	10,000
Large general aviation	500	1,000	2,500	5,000	10,000
Total	2,000	4,000	10,000	20,000	40,000
			Low Altitude Airways		
Large commercial	400	800	2,000	4,000	8,000
Large military	240	480	1,200	2,400	4,800
Large general aviation	400	800	2,000	4,000	8,000
Small general aviation	6,960	13,920	34,800	69,600	139,200
Total	8,000	16,000	40,000	80,000	160,000

(a)Flights per year.

(b)The number of small commercial and small military flights is assumed to be small compared to other types of flights.

Appendix C presents tables which summarize the input data that were used to calculate the annual frequencies of both small and large aircraft crashes at each of the eight sites. The frequencies were computed using the equations given above. The annual frequencies for all the sites and for large and small aircraft and helicopters are summarized in Table 4-12.

A major source of air crashes is the proximity of airports and heliports. This is of particular concern at APG, PBA, and PUDA. The air traffic for the APG analysis was supplied by PEO-PM Cml Demil (Ref. 4-19). The helicopter air traffic at PBA was estimated by SAIC (Ref. 4-12). The air traffic at PUDA was based on data collected at Pueblo Memorial Airport and communicated to GA by telephone. The helicopter traffic at TEAD is light and was assumed to be 15 flights per month.

The annual frequency of a crash into a specific facility is computed by multiplying the appropriate frequency taken from Table 4-12 by the effective target area of the facility (see Appendix C).

4.2.1.4. Meteorites. The frequency of meteorite strikes for meteorites 1.0 lb or greater is $4.3 \times 10^{-13}/ft^2$ (Ref. 4-20). For small meteorites (a ton or less), stone meteorites are approximately ten times more common than iron meteorites (Ref. 4-21). However, iron meteorites are more dense and tend to have higher impact velocities, and consequently, represent a significant portion of the total meteorites that can rupture munitions. Table 4-13 shows the size distribution of striking meteorites for both iron and stone meteorites. The table was compiled from the data presented in Refs. 4-20 and 4-21.

TABLE 4-12
SUMMARY OF AIRCRAFT CRASH PROBABILITIES
(Crashes/Square-Mile/Year)

Site	Large Aircraft	Small Aircraft	Helicopters
APG	5.3×10^{-7}	1.1×10^{-3}	6.7×10^{-3}
ANAD	7.9×10^{-6}	1.2×10^{-5}	N/A
LBAD	4.5×10^{-6}	1.8×10^{-7}	N/A
NAAP	4.6×10^{-6}	2.3×10^{-5}	N/A
PBA	1.5×10^{-6}	1.8×10^{-7}	1.1×10^{-4}
PUDA	5.9×10^{-5}	1.0×10^{-4}	N/A
TEAD	3.6×10^{-7}	3.5×10^{-6}	1.1×10^{-5}
UMDA	1.5×10^{-5}	1.2×10^{-5}	N/A

TABLE 4-13
SIZE DISTRIBUTION OF METEORITES WHICH ARE ONE POUND OR LARGER[a]

Weight Greater Than (lb)	Stone Meteorites[b]	Iron Meteorites[b]	All Meteorites[b]
1	0.9	0.1	1.0
2	0.3	3×10^{-2}	0.3
20	0.1	1×10^{-2}	0.1
200	3×10^{-2}	3×10^{-3}	3×10^{-2}
2,000	2×10^{-3}	2×10^{-4}	2×10^{-3}
20,000	3×10^{-4}	3×10^{-5}	3×10^{-4}

[a]Data compiled from Refs. 4-9 and 4-10.

[b]Fraction of total number of meteorites 1.0 lb or greater.

4.2.2. Internal Events

Table 4-14 summarizes the internal initiating events for the continued storage option. Also summarized in the table are the event occurrence frequencies. The bases for these frequencies are discussed in Section 5 and are not repeated here.

TABLE 4-14
LIST OF INTERNAL INITIATING EVENTS AND FREQUENCIES

Event	Frequency: Clothing Level A	C	F
STORAGE/HANDLING EVENTS (per operation)			
1. Munition drop from CHE (bulk containers)	3×10^{-5}	1.5×10^{-6}	3×10^{-6}
2. Munition drop from forklift (pallets or ST in overpacks)	3×10^{-4}	1.5×10^{-5}	3×10^{-5}
3. Munition drop from hand (single units)	6×10^{-4}	3×10^{-4}	6×10^{-5}
4. Forklift tine accident	1×10^{-4}	5×10^{-5}	1×10^{-5}
5. Forklift or CHE collision	4.3×10^{-6}	4.3×10^{-6}	4.3×10^{-6}
6. Leak between inspections (stored pallets)	Munition dependent		

4.3. REFERENCES

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5. SCENARIO LOGIC MODELS FOR STORAGE

5.1. SEQUENCE LIST AND EVENT TREES

The accident scenarios involving the interim storage of chemical munitions were categorized as follows:

1. External event-induced agent releases (e.g., earthquakes, aircraft crashes, etc.).

2. Releases due to leakage of munitions while in storage.

3. Releases from accidents that could occur during the isolation of leaking munitions while in storage.

4. Releases from accidents related to the handling of munitions during maintenance and surveillance.

For the first category (i.e., external events), the selection process described in Section 4.1 identified six initiating event families. These are discussed in Section 5.2. For the other categories (i.e., internal initiating events), there is one initiating event family for each category. A total of nine initiating event families resulted, as listed in Table 4-2. For each family, there were one or more specific sequences which were analyzed. Table 5-1 presents the list of accident sequences identified and evaluated for the continued storage option. Table 5-2 lists the sequences screened and gives the basis for the screening.

The event tree models are shown in Figs. 5-1 through 5-5. They will be discussed in the following sections by initiating event

TABLE 5-1
MASTER LIST OF STORAGE ACCIDENTS

Event ID	Description
SL1	Munition develops a leak between inspections.
SL2	Munition punctured by forklift tine during leaker-handling activities.
SL3	Spontaneous ignition of rocket during storage.[a]
SL4	Large aircraft direct crash onto storage area; fire not contained in 30 min. (Note: Assume detonation occurs if burstered munitions hit; fire involving burstered munitions not contained at all.)
SL5	Large aircraft indirect crash onto storage area; fire not contained in 30 min. (See note in SL4.)
SL6	Tornado-generated missiles strike the storage magazine, warehouse, or open storage area; munitions breached (no detonation).
SL7	Severe earthquake breaches the munitions in storage igloos; no detonations.
SL8	Meteorite strikes the storage area; fire occurs; munitions breached (if burstered, detonation also occurs).
SL9	Munition dropped during leaker isolation operation; munition punctured.
SL10	Storage igloo or warehouse fire from internal sources.[a]
SL11	Munitions are dropped due to pallet degradation.[a]
SL12	Liquefied propane gas (LPG) infiltrates igloo/building.[a]
SL13	Flammable liquids stored in nearby facilities explode; fire propagates to munition warehouse (applies to NAAP).[a]
SL14	Tornado-induced building collapse leads to breaching/detonation of munitions.[a]
SL15	Small aircraft direct crash onto warehouse or open storage yard; fire occurs; not contained in 30 min.

[a] Screened out for the reasons stated in Table 5-2.

TABLE 5-1 (Continued)

Event ID	Description
SL16	Large aircraft direct crash; no fire; detonation (if burstered).
SL17	Large aircraft direct crash; fire contained within 30 min (applies to nonburstered munitions only).
SL18	Small aircraft direct crash onto warehouse or open storage yard; no fire.
SL19	Small aircraft direct crash onto warehouse or open storage yard; fire contained in 30 min.
SL20	Large aircraft indirect crash onto storage area; no fire.
SL21	Large aircraft indirect crash onto storage area; fire contained in 30 min.
SL22	Severe earthquake leads to munition detonation.
SL23	Tornado-generated missiles strike the storage igloo and leads to munition detonation.
SL24	Lightning strikes ton containers stored outdoors.
SL25	Munition dropped during leaker isolation; munition detonates.
SL261	Earthquake occurs; NAAP warehouse is intact; no ton containers damaged; fire occurs.
SL262	Earthquake occurs; NAAP warehouse is intact; ton container damaged; no fire.
SL263	Earthquake occurs; NAAP warehouse is intact; ton container damaged; fire occurs.
SL264	Earthquake occurs; NAAP warehouse is damaged; ton containers damaged; no fire.
SL265	Earthquake occurs; NAAP warehouse is damaged; ton containers damaged; fire occurs.
SL271	Earthquake occurs; TEAD warehouses intact; munitions intact; fire occurs at one warehouse.
SL272	Earthquake occurs; TEAD warehouses intact; munitions intact; fire occurs at two warehouses.

TABLE 5-1 (Continued)

Event ID	Description
SL273	Earthquake occurs; one TEAD warehouse is damaged; munitions intact; fire occurs at one warehouse.
SL274	Earthquake occurs; one TEAD warehouse is damaged; munitions intact; fire occurs at two warehouses.
SL275	Earthquake occurs; two TEAD warehouses damaged; munitions intact; fire occurs at one warehouse.
SL276	Earthquake occurs; two TEAD warehouses damaged; munitions intact; fire occurs at two warehouses.
SL281	Earthquake occurs; UMDA warehouses intact; munitions intact; fire occurs at one warehouse.
SL282	Earthquake occurs; UMDA warehouses intact; munitions intact; fire occurs at two warehouses.
SL283	Earthquake occurs; UMDA warehouses intact; munitions in one warehouse damaged; no fire occurs.
SL284	Earthquake occurs; UMDA warehouses intact; munitions in one warehouse damaged; fire occurs at warehouse with damaged munitions.
SL285	Earthquake occurs; UMDA warehouses intact; munitions in one warehouse damaged; fire occurs at warehouse with undamaged munitions.
SL286	Earthquake occurs; UMDA warehouses intact; munitions in one warehouse damaged; fire occurs at two warehouses.
SL287	Earthquake occurs; UMDA warehouses intact; munitions in two warehouses damaged; no fire occurs.
SL288	Earthquake occurs; UMDA warehouses intact; munitions in two warehouses damaged; fire occurs at warehouse with damaged munitions.
SL289	Earthquake occurs; UMDA warehouses intact; munitions in two warehouses damaged; fire occurs at two warehouses.
SL2810	Earthquake occurs; one UMDA warehouse damaged; munitions in one warehouse damaged; no fire occurs.

TABLE 5-1 (Continued)

Event ID	Description
SL2811	Earthquake occurs; one UMDA warehouse damaged; munitions in one warehouse damaged; fire occurs at warehouse with damaged munitions.
SL2812	Earthquake occurs; one UMDA warehouse damaged; munitions in one warehouse damaged; fire occurs at two warehouses.
SL2813	Earthquake occurs; one UMDA warehouse damaged; munitions in two warehouses damaged; no fire occurs.
SL2814	Earthquake occurs; one UMDA warehouse damaged; munitions in two warehouses damaged; fire occurs warehouse with damaged munitions.
SL2815	Earthquake occurs; one UMDA warehouse damaged; munitions in two warehouses damaged; fire occurs at two warehouses.
SL2816	Earthquake occurs; two UMDA warehouses damaged; munitions in two warehouses damaged; no fire occurs.
SL2817	Earthquake occurs; two UMDA warehouses damaged; munitions in two warehouses damaged; fire occurs at both warehouses.

TABLE 5-2
ACCIDENT SEQUENCES ELIMINATED FROM DETAILED ANALYSIS

Accident Sequence	Description	Basis for Elimination
1. SL3	Spontaneous ignition of rocket during storage.	Recent study indicates that the propellant is stable and will continue to be so for some time (Ref. 5-18). There is an enhanced monitoring program to sample propellant in storage. There are also accelerated tests being performed to provide advanced warning of the onset of propellant destabilization.
2. SL11	Munitions are dropped and damaged due to pallet degradation.	The pallets in storage are in very good condition and are expected to remain so for many more years. The munitions are periodically inspected, and if deterioration is observed, the causes are identified and corrected, and the degraded pallet replaced.
3. SL10	Storage igloo or building fire from internal sources.	There is no source of fire in the storage igloos or storage buildings (Ref. 5-1).
4. SL12	Liquid propane gas (LPG) infiltrates igloo/building.	LPG cloud due to release of largest conceivable inventory (35,000 gal) cannot deposit flammable concentration inside the igloo or building (Ref. 5-1).
5. SL13	Flammable liquids stored in nearby facilities explode; fire propagates to munition warehouse (applies to NAAP only).	Several empty storage vessels are located approximately 350 ft from the nearest ton containers outside the exclusion area at NAAP. These tanks were used in conjunction with the former VX production facility. It

TABLE 5-2 (Continued)

Accident Sequence	Description	Basis for Elimination
		is the Army's position to ensure that these tanks will remain empty while munitions are being stored at the NAAP warehouse.
6. (a)	Tornado-induced munition drop leads to munition ignition and detonation.	Calculations indicate that tornado winds at 200 mph will not lift munitions (Ref. 5-2).
7. (a)	Tornado winds lift ton containers and drop them to the ground; container ruptures.	Same as item 6.
8. (a)	A vehicle fire spreads to the storage area/igloo and sets off munitions	Previous analysis indicated that even if the fire was just outside the igloo and the igloo door was open, the munition thermal failure threshold will not be exceeded (Ref. 5-1).
9. (a)	Electrostatic ignition of rocket motor leads to detonation and fire.	Previous study indicated there was no source of spark capable of igniting a rocket motor accidentally (Ref. 5-1).
10. (a)	Electromagnetic pulse (EMP) effects cause detonation.	Previous study concluded there were no sources of EMP of sufficient strength to cause damage to the munitions (Ref. 5-1).

(a) Sequence number not identified in GA's list.

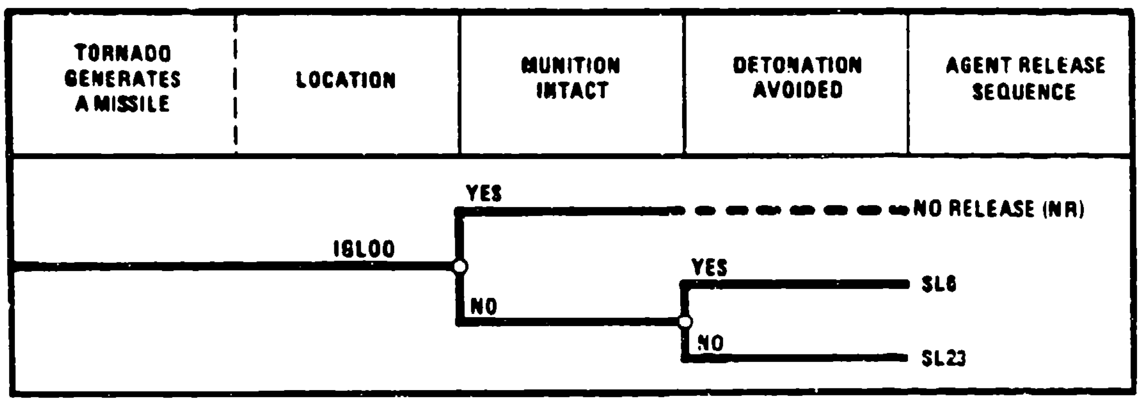

Fig. 5-1. Agent release indicated by tornado-generated missiles

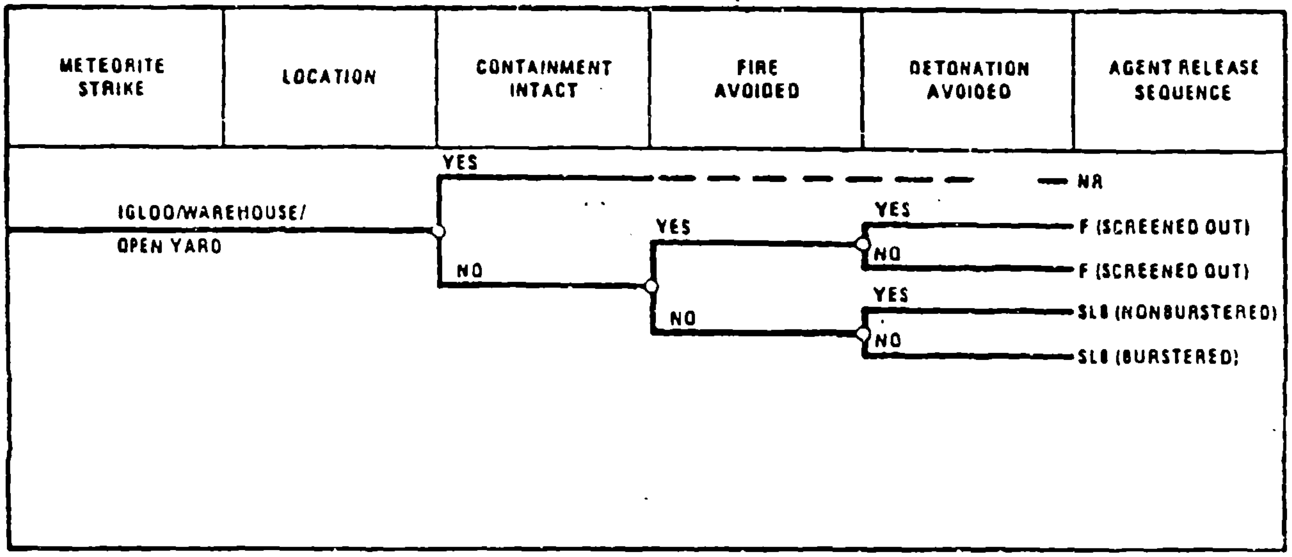

Fig. 5-2. Meteorite-induced agent release

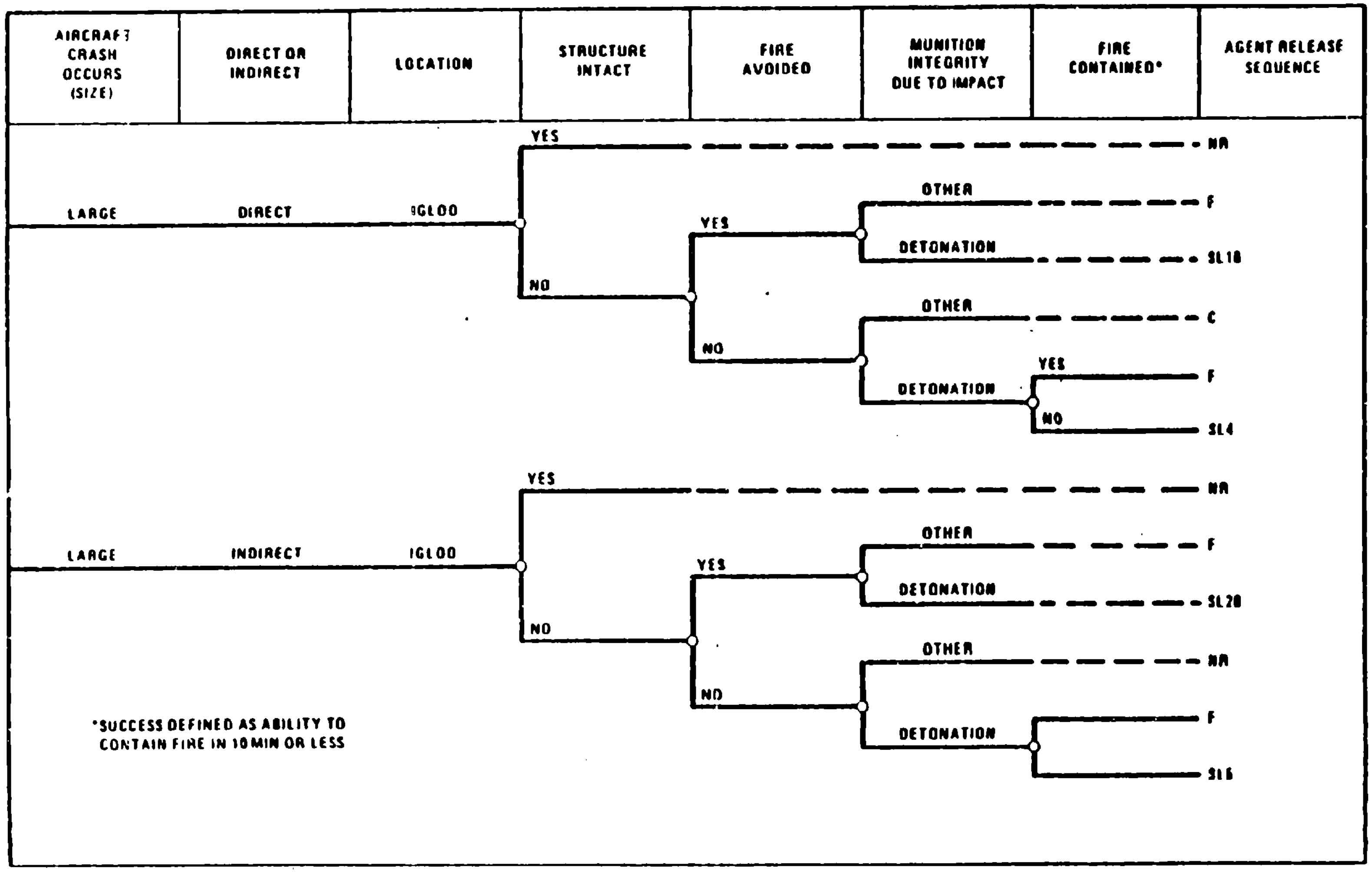

Fig. 5-3. Large aircraft crash onto storage igloos containing burstered munitions

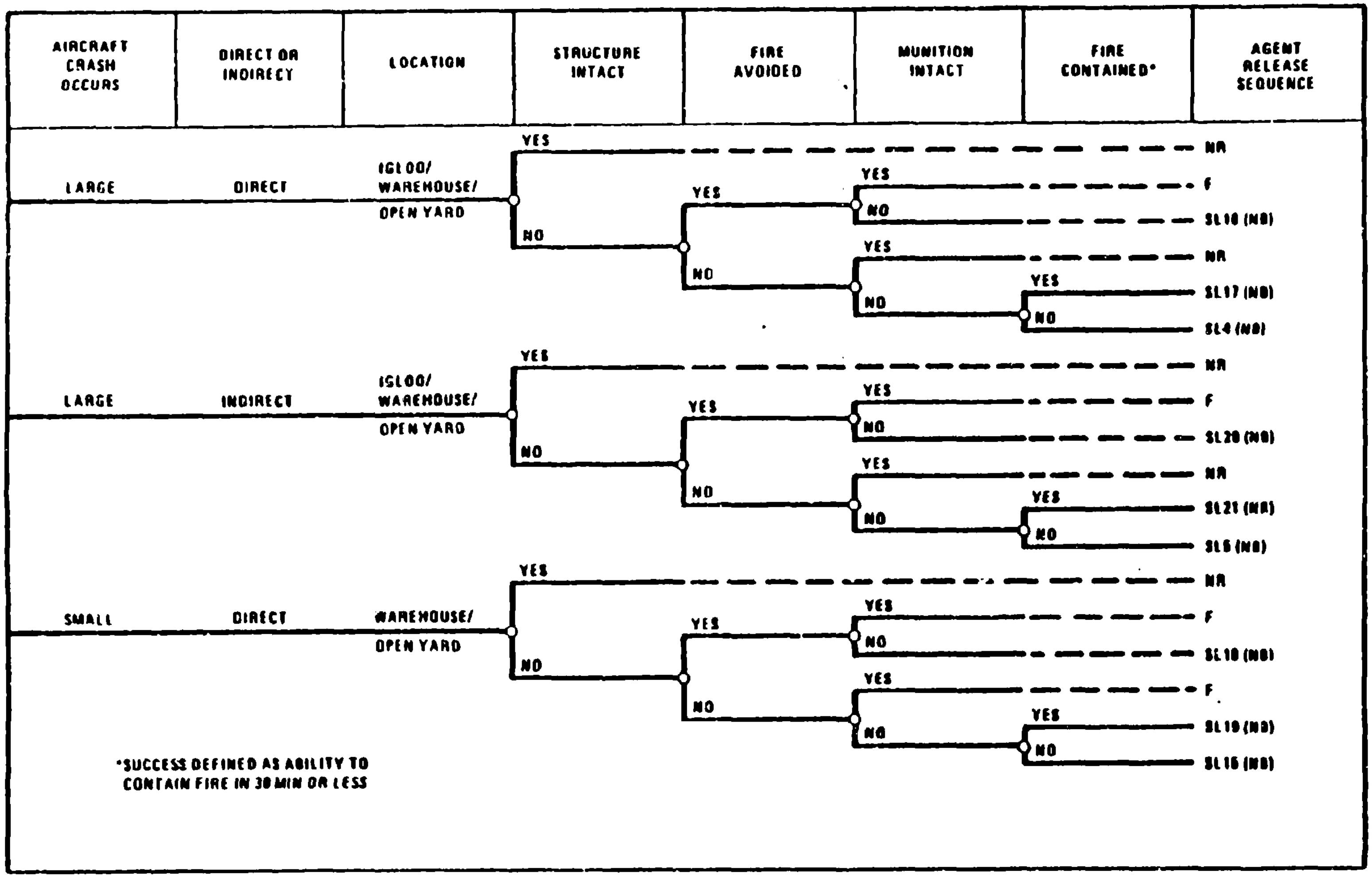

Fig. 5-4. Aircraft crash onto storage facilities with nonburstered (NB) munitions

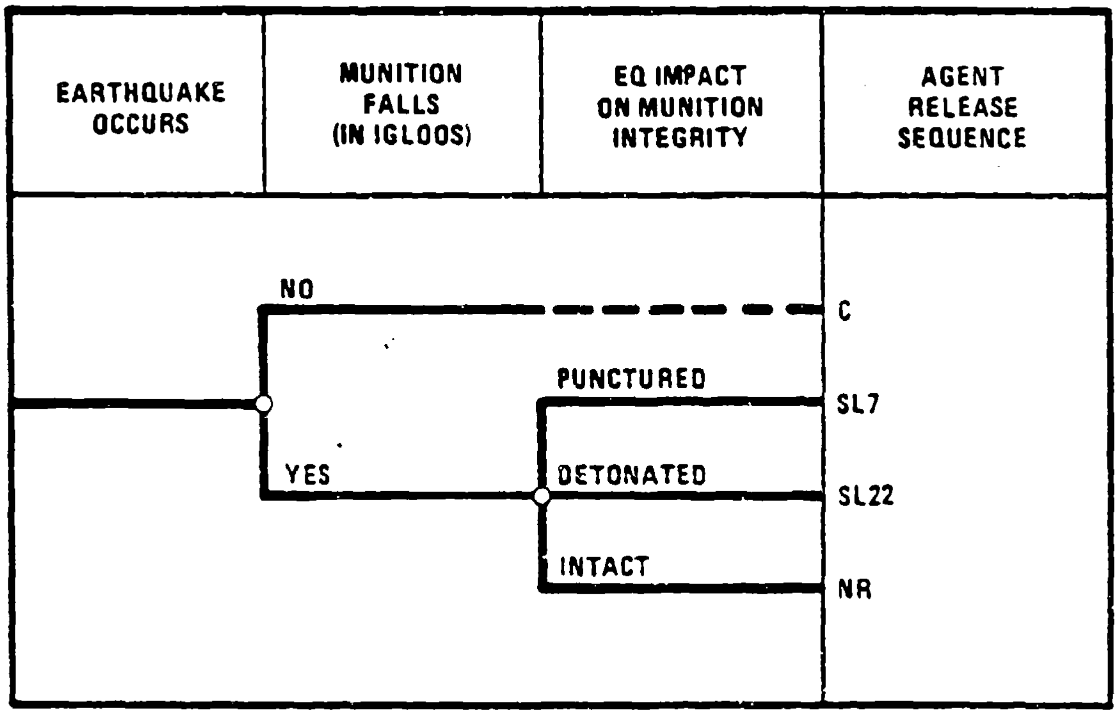

Fig. 5-5. Earthquake-induced agent releases involving munitions in storage igloos

category. In these event trees, NR refers to no release of agent, and F and C mean that the sequence was screened on the basis of low frequency or low consequence, respectively.

5.2. EXTERNAL EVENTS

The external events that were evaluated include:

- Tornadoes and high winds.
- Meteorite strikes.
- Aircraft crashes.
- Earthquakes.
- Lightnings.
- Floods.

In general, the amount of agent released to the atmosphere from accidents induced by such events depends on the extent of damage incurred to the building structure and the munition itself. The munitions are currently stored in igloos, warehouses, or open storage yards. Section 3 discusses the types of storage structures present at each CONUS site, as well as the kinds of munitions stored.

5.2.1. Tornadoes and High Winds

The accident scenarios identified involve the breaching of the munitions in the storage facilities (i.e., igloos, warehouses, or open yards) by tornado- or high-wind-generated missiles. This failure mode was determined to be more credible than that identified in sequence SL14, which is a tornado/high-wind-induced building collapse that could lead to the crushing of munitions by the falling structure. For UBC-designed structures such as a warehouse, the wind loads will fail the walls of the structure before the structure will collapse. Storage igloos have been designed to resist the direct effects of tornadoes with winds up to 320 mph except for the possibility of missiles breaching the igloo doors (Ref. 5-1). For the above reasons, sequence SL14 has been screened out from further analysis.

The event tree developed to define relevant accident sequences is shown in Fig. 5-1. Neither of the accident sequences (SL6 and SL23) could be screened out initially as more detailed quantitative analysis is required to determine the necessary wind velocity to generate missiles which could penetrate the munitions. Hence, both accident sequences shown in the event trees were quantified.

Essentially, the missile penetration of the munition occurs if (1) a tornado or extremely high wind occurs with a velocity sufficient to generate a missile that could penetrate the igloo door, warehouse wall, or transportation container wall, and the munition itself; and (2) the missile actually hits the target munition.

The probability of a missile hitting and rupturing a munition is the product of four variables: (1) the probability that the velocity vector of the missile is nearly perpendicular to the target; (2) the probability that the missile is oriented properly to penetrate the target; (3) the number of missiles per square foot of wind; and (4) the target area. More details on the derivation of these variables are provided in Appendix C and Ref. 5-2.

If the missile hits a burstered munition, two failure modes are possible: (1) the munition is opened up due to puncture or crush, or (2) the missile impact causes munition detonation due to the application of a force greater than the "undue force." The undue force is defined as "a force greater than that generally required to assemble the munition" or as "any force which could cause deformation to the munition (other than minor surface deformation) or damage to the explosive train" (Ref. 5-3).

5.2.1.1. Storage Magazines. The analysis of the vulnerability of the igloo door to the tornado-generated missile considered the two types of igloo doors present at the CONUS sites, i.e., steel and concrete. PBA and TEAD have igloos with either steel or concrete doors, while the igloos at ANAD, LBAD, PUDA, and UMDA have steel doors only. For conservatism, all igloos at PBA and TEAD were assumed to have concrete igloo doors.

The steel doors require a missile velocity of 94 mph for penetration by a 3-in. steel pipe or 66 mph for penetration by a utility pole. For the concrete doors, the penetration velocity for a 3-in. steel pipe is 66 mph and for the utility pole, 54 mph. After penetrating the door, the remaining missile velocity must be large enough to rupture the munition. The formula for the required initial missile velocity is as follows:

$$V_I = V_d^2 + V_m^2 \quad , \qquad (5\text{-}1)$$

where V_I = required initial velocity,

V_d = required velocity to penetrate the door,

V_m = required velocity to rupture the munition.

In order for a missile to reach the velocity required to penetrate the igloo door and the munitions inside, a wind with a significantly higher velocity is required. Table 5-3 presents the relationship between wind velocity and missile velocity.

The frequency of a wind-generated missile penetrating an igloo and a munition inside the igloo, is the product of the following:

1. The frequency of a tornado or wind which has sufficient velocity to generate a missile that can penetrate the igloo and munition.

TABLE 5-3
WINDBORNE MISSILE VELOCITIES[a]

Design Wind Speed	Horizontal Missile Velocity[b] (mph) 100	150	200	250	300	350	Maximum Height (ft)
Timber plank	60	72	90	100	125	175	200
Three-inch-diameter standard pipe	40	50	65	85	110	140	100
Utility pole	(c)	(c)	(c)	80	100	130	30
Automobile	(c)	(c)	(c)	25	45	70	30

[a]Source: Ref. 5-4.

[b]Vertical velocities are taken as 2/3 the horizontal missile velocity. Horizontal and vertical velocities should not be combined vectorially.

[c]Missile will not be picked up or sustained by the wind; however, for this analysis, any initial missile velocity of 80 mph or less was assigned a wind velocity of 250 mph.

2. The probability of a missile penetrating the igloo and hitting the munition in such a way as to cause damage and is calculated as follows:

$$P_p = P_d \times P_o \times D_e \times A_t \quad , \tag{5-2}$$

where P_d = probability that the velocity of the missile is nearly perpendicular to the target plane,

P_o = probability that the missile is oriented to penetrate the target (i.e., missile not tumbling or going sideways),

D_e = density of number of missiles per square foot of wind,

A_t = target area.

Details on the calculation of these variables are given in Ref. 5-2.

The site-specific tornado frequency versus velocity curves has been presented in Section 4. Two types of missiles were initially considered: (1) a 3-in. pipe and (2) a utility pole. For all munition types, it was found that the utility pole had a higher probability of penetrating munitions.

Tables 5-4 and 5-5 present the wind velocities required to generate missiles which have sufficient velocity to penetrate the igloo door and the various munitions stored inside. Table 5-6 presents the annual frequencies of these winds occurring at each of the sites that have igloos. The frequencies were read from the curves presented in Figs. 4-9 through 4-11. The conditional probability of a missile hitting the igloo door and the munitions stored inside is 3.2×10^{-6} (see Appendix C).

TABLE 5-4

MISSILE PENETRATION THROUGH STEEL IGLOO DOORS AND MUNITIONS

Munition	Missile	Munition Rupture Velocity (mph)	Door Penetration Velocity (mph)	Required Initial Missile Velocity (mph)	Required Wind Velocity (mph)
Ton container	3-in. pipe	108	94	143	>350
	Utility pole	67	66	94	285[a]
4.2-in. mortar	3-in. pipe	60	94	112	303
	Utility pole	8	66	67	250[a]
750-lb bomb	3-in. pipe	101	94	138	347
	Utility pole	63	66	91	278[a]
8-in. projectile	3-in. pipe	162	94	187	>350
	Utility pole	25	66	71	250[a]
M23 land mine	3-in. pipe	43	94	103	286
	Utility pole	6	66	66	250[a]
M55 rocket	3-in. pipe	22	94	97	274
	Utility pole	8	66	67	250[a]

[a]Critical missile for munition.

TABLE 5-5
MISSILE PENETRATION THROUGH CONCRETE IGLOO DOORS AND MUNITIONS

Munition	Missile	Munition Rupture Velocity (mph)	Door Penetration Velocity (mph)	Required Initial Missile Velocity (mph)	Required Wind Velocity (mph)
Ton container	3-in. pipe	108	66	127	329
	Utility pole	67	54	86	285[a]
4.2-in. mortar	3-in. pipe	60	66	89	258
	Utility pole	8	54	55	250[a]
750-lb bomb	3-in. pipe	101	66	121	318
	Utility pole	63	54	83	258[a]
8-in. projectile	3-in. pipe	162	66	175	>350
	Utility pole	25	54	60	250[a]
M23 land mine	3-in. pipe	43	66	79	235[a]
	Utility pole	6	54	54	250
M55 rocket	3-in. pipe	22	66	70	213[a]
	Utility pole	8	54	55	250

[a]Critical missile for munition.

TABLE 5-6
FREQUENCY OF A WIND HAZARD SUFFICIENT TO BREACH
MUNITIONS IN STORAGE MAGAZINES[a]
(Per Year)

	ANAD	LBAD	PBA[b]	PUDA	TEAD[b]	UMDA
Cartridges and mortars	1.5E-6	--	--	1.0E-7	1.8E-9	--
Projectiles	1.5E-6	1.5E-6	--	1.0E-7	1.8E-9	1.8E-9
Mines	1.5E-6	--	2.6E-6	--	4.2E-9	1.8E-9
Rockets	1.5E-6	1.5E-6	6.1E-6	--	1.5E-8	1.8E-8
Ton containers	3.8E-7	--	--	--	7.5E-10	2.4E-10
Bombs	--	--	--	--	1.1E-9	3.6E-10
Spray tanks	--	--	--	--	--	1.1E-9

(a)Frequencies obtained from the curves presented in Figs. 4-9 through 4-11.

(b)Concrete doors.

5.2.1.2. Warehouses. The warehouses at TEAD are designed for 100-mph wind loads (Ref. 5-1). Assuming that the warehouses at NAAP and UMDA are designed to the UBC requirements, they should be designed for at least 70 mph winds. An analysis of the UBC requirements shows that winds will fail the walls of UBC designed structures before the frame of the structure will fail. Based on the margins of safety required by the UBC, the concrete walls of the warehouses at TEAD are not expected to be breached by winds less than 160 mph. Breaching of the concrete walls is expected to involve cracking and spalling of the concrete and the possibility of the wall partially separating from the frame. The sheet metal walls of the warehouses at NAAP and UMDA are expected to be blown away by 115-mph winds. Neither of these failures are expected to damage the bulk containers.

In order for a wind blown missile to penetrate a spray tank in a warehouse at TEAD, it must pass through the 6-in. concrete wall, the spray tank overpack, and finally the spray tank itself. This would require a 283-mph wind.

A 250-mph wind can generate a missile that will penetrate an unprotected ton container. Since a 115-mph wind is expected to blow away the walls of the warehouses at NAAP and UMDA, the walls will offer no protection. Therefore, a 250-mph wind has the potential to generate missiles that will penetrate the ton containers stored in these warehouses. Table 5-6 presents the frequency of occurrence of such winds at these sites. The conditional probability of a missile hitting a ton container in an orientation which could breach the container is 2.2×10^{-4} at NAAP and 2.7×10^{-4} at UMDA (see Appendix C).

5.2.1.3. Open Storage. Ton containers are stored in open storage at APG, PBA, and TEAD. A wind velocity of 250 mph is required to generate a missile that can penetrate these ton containers. The frequencies of generating the 250-mph wind are presented in Table 5-7. The conditional

TABLE 5-7
FREQUENCIES FOR WIND-GENERATED MISSILE PENETRATION
OF TON CONTAINERS AND SPRAY TANKS STORED IN
WAREHOUSES AND OPEN STORAGE

Site	Storage	Required Wind	Frequency of Wind	Probability of Hitting and Rupturing TC
APG	Open	250	1.0E-7	6.6E-4
PBA	Open	250	1.5E-6	6.6E-4
NAAP	Warehouse[a]	250	1.5E-6	2.2E-4
UMDA	Warehouse[a]	250	1.8E-9	2.7E-4
TEAD	Warehouse[b]	283	2.7E-10	4.4E-4

[a] Metal walls.

[b] Concrete walls.

probability of a missile hitting a ton container in an orientation which could breach the container is 6.6×10^{-4} (see Appendix C).

5.2.1.4. Tornado-Generated Missiles Cause Munition Detonation. The analysis of scenario SL23 included the estimation of the probability that a missile impacting a munition would cause it to detonate or in the case of rockets, cause the rocket motor to ignite and subsequently detonate the burster. The data presented in Ref. 5-5 indicated that a projectile with Comp B explosive could ignite when subjected to a minimum impact velocity of 123 mph. Because the conditions of the tests described in Ref. 5-5 do not fully apply to the conditions being considered here (i.e., the shell casing provides protection for the bursters), it is assumed that there is a 50% chance that a munition will detonate at 123 mph. Furthermore, Army data indicate that dropping of thousands of burstered munitions from 40 ft did not lead to any detonations (Ref. 5-6). However, these are newer munitions and may not fully represent the chemical munitions in the stockpile. Therefore, based on a consensus of risk experts (Ref. 5-19), an estimated failure probability of 10^{-6} per munition drop was assigned to all drops of 6 ft or lower (equivalent to a free fall drop of 13.5 mph).

To determine the probability of detonating a munition at an impact velocity equivalent to that of a missile required to penetrate the igloo and the munition, we assumed a lognormal distribution and derived the necessary parameters (e.g., standard deviation and standard normal deviate) from these two data points. The calculation details are given in the calculation sheets (Ref. 5-2).

The overall frequency for this scenario is the product of the following:

1. The frequency of a tornado or wind which has sufficient velocity to generate a missile that can penetrate the igloo and munition.

2. The probability of a missile penetrating the igloo and hitting the munition in such a way as to cause damage.

3. The probability of burster detonation from impact.

The values for the first two variables have already been presented in Section 5.2.1.1. The probability of a detonation given penetration of burstered munitions stored inside the igloos with steel doors is 0.07 and for concrete doors, 0.055. See Ref. 5-2 for calculations.

5.2.2. Meteorite Strikes

Like tornado-generated missiles, meteorites striking the igloos, warehouses, and the outdoor yards can lead to a significant amount of agent release. The consequence of such an accident is more severe than that from a tornado-generated missile because meteorite strikes generally involve fires. Hence, if burstered munitions are involved, explosive detonations could occur from the fire or from direct impact, leading to instantaneous agent releases.

The event tree developed for meteorite-initiated accidents is shown in Fig. 5-2. The scenarios could not be subjected to any preliminary screening without doing a more detailed analysis of the what type (stone or iron) and size of meteorite is capable of penetrating munitions stored igloos, warehouses, or outdoors. The only identified accident sequence is SL8.

Storage Magazines

In this scenario the meteorite penetrates the storage magazine and ruptures some of the munitions stored inside. The meteorite is expected to be sufficiently hot to cause ignition of the exposed burster, propellant, and/or agent. The fire is expected to spread, resulting in the destruction of the entire inventory of the storage magazine.

Warehouses

This scenario is similar to the storage magazines. The meteorite penetrates the warehouse and ruptures some of the bulk munitions stored inside. The meteorite causes the ignition of the exposed agent. Fire spreads and results in the destruction of the entire warehouse inventory.

Open Storage

In this scenario, the meteorite directly impacts and ruptures some ton containers. The heat from the meteorite is expected to ignite the exposed agent, but is not expected to cause the rupture of additional munitions.

5.2.2.1. Meteorite Strike Accident Analysis. About 3500 meteorites, each weighing over 1 lb, strike the earth each year; the majority of them are of small sizes (Ref. 5-8). Given the earth's surface area of 5.48×10^{15} ft^2, the frequency of meteorite strikes for meteorites weighing 1.0 lb or greater is 6.4×10^{-13}/ft^2 (Ref. 5-8). For meteorites one ton or less, stone meteorites are approximately 10 times more common than iron. However, iron meteorites are more dense and tend to have higher impact velocities and therefore represent a significant portion of the total meteorites that can rupture the munitions. Section 4.2 presents the size distribution of both iron and stone meteorites, compiled from data presented in Refs. 5-8 and 5-9.

For agent to be released, the meteorite has to penetrate the storage structure and the munition wall. In the case of an igloo, this would require initial penetration of a 6-in. concrete roof. The minimum meteorite impact velocity that would penetrate the earth cover and collapse the 6-in. concrete roof is 1500 fps for stone meteorite and

3800 fps for iron meteorite. The overall frequency of a meteorite capable of penetrating and rupturing the munitions in the igloo is:

$$P = F\ (F_s + F_i)\ A \times S \quad , \qquad (5\text{-}4)$$

where F = the frequency of a meteorite weighing 1 lb or more striking the earth, $6.4 \times 10^{-13}/ft^2$,

F_s = fraction of stone meteorites which can penetrate the target,

F_i = fraction of iron meteorites which can penetrate the target,

A = target area (igloo, warehouse, or open storage yard,

S = spacing factor.

Table 5-8 presents the frequencies for meteorite penetration of munitions stored in the various storage configurations along with the size of the meteorites required to penetrate the munitions and the data required to evaluate Eq. 5-4. Supporting calculations are presented in Ref. 5-2, and the methodology is discussed in Appendix C.

5.2.3. Aircraft Crashes

The sequences describing the effects of an aircraft crash on munitions in storage are SL4, SL5, SL15, SL16, SL17, SL18, SL19, SL20, and SL21.

The effects of large (>12,500 lb) and small (12,500 lb or less, including helicopters) aircraft crashes on the munitions in storage igloos, warehouses, and open yards were evaluated. Because of the potential for large quantities of fuel to be carried by large aircraft and the potential for large, high-velocity missiles (e.g., engines), the large aircraft crash scenarios were further divided into direct and indirect crashes. For direct and indirect large aircraft crashes onto the storage area that do not result in fire, it is assumed that the

TABLE 5-8
METEORITE REQUIRED FOR PENETRATION OF MUNITIONS IN STORAGE

Storage Area	Munition	Stone Meteorite Weight (lb)	Stone Meteorite Fraction (fs)	Iron Meteorite Weight (lb)	Iron Meteorite Fraction (fi)	Target Area (ft^2) (A)	Spacing Factor (s)
Igloo	All	1,000	0.02	200	0.003	960	0.5
Warehouse-NAAP	Ton container	20	0.11	2	0.03	22,000	0.5
Warehouse-UMDA	Ton container	20	0.11	2	0.03	46,000	0.4
Warehouse-TEAD	Spray tank	100	0.08	10	0.02	67,000	0.4
Open	Ton container	20	0.11	2	0.03	139[a]	1.0

[a]Area cf one pallet (15 ton containers stacked two high).

[b]700 x 220 ft (Ref. 5-17).

impact of the crash is strong enough to cause the detonation of burstered munitions.

For a small aircraft crash adjacent to the storage site to produce a credible event, the crash would have to be so close that it would virtually be a direct hit. Therefore, the small aircraft crash scenarios address only direct hits into the storage areas including holding areas.

The event trees developed to identify the agent release sequences from aircraft crashes are shown in Figs. 5-3 and 5-4.

5.2.3.1. Aircraft Crash Accident Analysis. In summary, the following general assumptions were made in deriving the large/small aircraft accident scenarios:

1. For large aircraft crashes onto burstered munitions, it is assumed that detonations will occur for both indirect and direct hits, and, if a fire occurs, it is uncontained.

2. No small aircraft crashes were assumed to be able to sufficiently damage the igloo to cause agent releases.

Direct Crash of Large Aircraft (Sequences SL4, SL16, SL17)

For a direct aircraft crash, the target area is the surface area of the building or open yard.

Storage Magazines. The direct crash of the main body of a heavy military or commercial aircraft into the shell or front face of a storage magazine (igloo) can breach the igloo and allow crash-generated missiles and/or aviation fuel to enter into the igloo. There is a high probability that one or more munitions will be crushed or punctured by the missiles. Burstered munitions could also detonate from impact. If the crash produces a fire, the fire is expected to spread through the igloo, resulting in the destruction of the entire igloo inventory.

Warehouses. A warehouse is not expected to offer any substantial resistance to crash of a large aircraft. The direct impact of any part of a large aircraft will breach the warehouse and subject the stored munitions to crash-generated missiles. Bulk containers will be crushed or punctured. If the crash produces a fire that is not contained, the destruction of the entire inventory is expected.

Open Storage. The crash of a large aircraft into an open area is expected to breach a large number of ton containers. If the crash produces a fire, and it is not contained, it is expected to breach additional containers in the immediate vicinity of the initial container that is on fire.

Indirect Crash of a Large Aircraft (Sequences SL5, SL20, SL21)

For an indirect crash, the target area is determined by increasing all perimeters for the direct crash by 200 ft.

Storage Magazines. Should a large aircraft crash adjacent to an igloo, the area that is most vulnerable is the igloo door. The crash-generated missiles can breach the igloo door which essentially provides a pathway to the breaching of munitions in the line of site of the missile. Alternatively, the igloo door may already be open at the time of the crash and the missile could directly penetrate the munitions. If fire is involved, the missile could already be on fire or the fire could propagate into the igloo opening. Thus, if fire is not contained, the amount of agent release is the same as for the direct crash of a large aircraft into an igloo.

Warehouses. The designs of the warehouses are such that the crash of a large aircraft into an area adjacent to a warehouse may also breach the warehouse if the aircraft is flying towards the warehouse at the time of the crash. The amount of munitions that are initially impacted would be less than the direct crash scenario. However, if fire is involved and uncontained, the amount of agent release is the same as for the direct crash of large aircraft into a warehouse.

Open Storage. The accident scenario for the crash of a large aircraft into an area adjacent to the open storage area considers that there is a 50% chance that some ton containers would be breached by the crash-generated missile. If fire is involved and not contained, additional containers would rupture due to excessive heating.

Direct Crash of a Small Aircraft (Sequences SL15, SL18, SL19)

Storage Magazines. Due to the high strength of the storage magazine, the crash of a small aircraft is not expected to breach an igloo or affect the structural integrity of an igloo.

Warehouses. The crash of a small aircraft into a warehouse would very likely breach the warehouse. The resulting crash-generated missiles are expected to crush or puncture some munitions. If the crash produces a fire and it is not contained, the fire would involve the entire inventory.

Open Storage. The crash of a small aircraft into an open storage area is similar to the large aircraft crash into an open storage area except a smaller number of ton containers is breached.

5.2.3.2. Aircraft Crash Frequency. The frequency of an aircraft crashing while in an airway or in the vicinity of an airport can be computed as shown in Section 4.2.1.3.

The annual frequency of a crash into a specific facility was computed by multiplying the appropriate frequency taken from Table 4-13 by the effective target area of the facility (see Appendix C). Table 5-9 summarizes these annual frequencies. The calculations of the effective

TABLE 5-9

DATA BASE FOR AIRCRAFT CRASH-INITIATED SCENARIOS FOR STORAGE

24-Jul-87

DATA BASE FOR AIRCRAFT CRASH-INITIATED SCENARIOS FOR STORAGE

EVENT	VARIABLE ID	FREQUENCY OR PROBABILITY	UNIT	ERROR FACTOR	REFERENCE
Large aircraft direct crash storage area:					
ANAD - 60 FT IGLOO	LDANI60	4.5E-10	per facility	10	Ref. 5-2
ANAD - 80ft igloo	LDANI80	6.0E-10	year	10	
APG - open	LDAPOP	2.4E-09		10	
LBAD - 89ft igloo	LDLBI89	3.7E-10		10	
NAAP - wh	LDNAWH	3.6E-09		10	
PBA - 80ft igloo	LDPBI80	1.1E-10		10	
- open	LDPBOP	1.7E-08		10	
PUDA - 80 ft igloo	LDPUI80	4.5E-09		10	
TEAD - 80 ft igloo	LDTEI80	2.7E-11		10	
- 89 ft igloo	LDTEI89	3.0E-11		10	
- wh	LDTEWH	8.7E-10		10	
- open	LDTEOP	7.9E-09		10	
UMDA - 80 ft igloo	LDUMI80	1.1E-09		10	
- wh	LDUMWH	2.5E-08			
Large aircraft indirect crash :					
ANAD - 60 ft igloo	LAANI60	5.5E-08	per facility	10	Ref. 5-2
ANAD - 80ft igloo	LAANI80	5.7E-08	year	10	
APG - open	LAAPOP	9.4E-09		10	
LBAD - 89ft igloo	LALBI89	3.3E-08		10	
NAAP - wh	LANAWH	5.0E-08		10	
PBA - 80ft igloo	LAPBI80	1.1E-08		10	
- open	LAPBOP	3.5E-08		10	
PUDA - 80 ft igloo	LAPUI80	4.3E-07		10	
TEAD - 80 ft igloo	LATEI80	2.6E-09		10	
- 89 ft igloo	LATEI89	2.7E-09		10	
- wh	LATEWH	7.9E-09		10	
- open	LATEOP	1.3E-08		10	
UMDA - 80 ft igloo	LAUMI80	1.1E-07		10	
- wh	LAUMWH	1.3E-07		10	
Igloo breached given direct crash	ID	8.0E-01	none	1.4	EJ
Igloo breached given indirect crash	IA	2.0E-03	none	3	Ref. 5-2
Whse/outdoor contnr brched (dir. crash)	WHD	1.0E+00	none	none	EJ
Whse brchd given indirect crash	WHA	1.7E-01	none	3	Ref. 5-2
Outdoor contnr brchd (indir. crash)	OA	5.1E-01	none	1.4	Ref. 5-2
Crash does not involve fire	NF	3.3E-01	none	none	Ref. 5-11

TABLE 5-9 (Continued)

DATA BASE FOR AIRCRAFT CRASH-INITIATED SCENARIOS FOR STORAGE

EVENT	VARIABLE ID	FREQUENCY OR PROBABILITY	UNIT	ERROR FACTOR	REFERENCE
Crash results in fire	YF	4.2E-01	none	none	Ref. 5-11
Fire not contnd in 1/2 hr (burstrd)	FNCB	1.0E+00	none	none	Ref. 5-2 and Appendix J
Fire contnd in 1/2 hr (nonburstrd)	FCNB	3.4E-04	none	3	Ref. 5-2 and Appendix J
Fire not contnd in 1/2 hr (nonburstrd)	FNCNB	1.0E+00	none	none	Ref. 5-2 and Appendix J
Fire contained (wh or op) small	SFNB	1.9E-02	none	3	Ref. 5-2
Small aircraft crash warehouse NAAP	SANAAP	1.8E-08	per year	10	Ref. 5-2
Small aircraft crash warehouse UMDA	SAUMDA	2.0E-08		10	Ref. 5-2
Small aircraft crash warehouse TEAD	SATEAD	3.3E-08		10	Ref. 5-2
Small aircraft crash open APG	SAOAPG	3.6E-05		10	Ref. 5-2
Small aircraft crash open PBA	SAOPBA	1.3E-06		10	Ref. 5-2
Small aircraft crash open TEAD	SAOTEAD	3.2E-07		10	Ref. 5-2

areas are contained in Ref. 5-2 and take into account such factors as aircraft wing span, facility height, and facility vulnerability.

5.2.3.3. <u>Probability of Fire Resulting From an Aircraft Crash</u>. The probability of a fire resulting from the crash has been estimated to be 0.45 (Ref. 5-12). The successful containment of the fire is defined here to be 0.5 h for unpackaged nonburstered munitions. This time was selected based on the thermal failure threshold data presented in Appendix F, which indicate that direct heating of ton containers for 36 min leads to hydraulic rupture. For unpackaged burstered munitions, the thermal failure threshold range from 4 min for rockets to 23 min for mines. Since the Army policy is not to fight a fire involving direct heating of burstered munitions, the probability of the "failure to contain fire" event is essentially 1.0.

Thus, the amount of agent released from bulk containers subjected to aircraft crash fires depends on the ability to contain the fire. If fire is allowed to progress for more than 30 min, more containers will rupture.

The ability of the fire-fighting team to extinguish an aircraft crash fire depends on many variables such as the precise crash site, the burn time of the resulting fire, the availability of resources necessary to contain the fire, etc. If fire fighters arrive at the crash site in a relatively short period of time, the fire will be easier to extinguish since it is not likely to have spread very far. Because the fire will involve chemical agent, additional precautions will have be taken before the fire-fighting team can start extinguishing the fire. Their arrival at the perimeter of the MDB or MHI is assumed to occur about 5 min after the crash. The crew will have to put on agent protective clothing in addition to their normal, fire-fighting suits of thermal protective clothing. Donning these clothes and checking for proper mask fit would take several more minutes, if it is assumed that the crew was partially dressed; i.e., in a standby readiness mode. Because of all the detection, observation, communication, preparation, and travel tasks involved, it is estimated that it would take the fire-fighting team 15 min to get to the scene of the fire.

Once at the scene, the time it takes to actually extinguish the fire is difficult to estimate. GA interviewed local fire fighting personnel to get their opinion on how long it takes to extinguish a fire from a small aircraft crash versus large aircraft crash. No definite time can be given because of the many variables involved. But based on local experience, it would take 1 to 3 h to extinguish a fire from a small aircraft; while it would take 3 to 10 h for a large aircraft fire. Using the lognormal distribution, GA then derived the probability of containing the fire in 0.5 h or less and took no credit for the first 15 min of the fire. More details are provided in the calculation sheets (Ref. 5-2).

5.2.4. Earthquakes

5.2.4.1. Storage Magazines. The earthquake-initiated accident affecting the storage igloos assumes that the earthquake causes the munitions in the igloo to fall and be punctured given the presence of a probe on the igloo floor or the fall could cause a burstered munition to detonate (Sequence SL7). This scenario is modeled using the event tree illustrated in Fig. 5-5.

The storage magazines are expected to survive the largest credible earthquake with little or no damage. Some cracking or spalling of the concrete is possible, but this should not produce a threat to the munitions or significantly change the containment capability of the magazine. Igloos have been tested by very large external explosions and have survived without damage (Ref. 5-11). The data from these tests indicate that the igloo experienced accelerations which were in excess of 20 g. Though an explosion is not as potentially damaging to an igloo as an earthquake of equal acceleration, the similarities are sufficient to conclude that a very large earthquake, in the range of 1.0 g, is not likely to damage an igloo.

Sequence SL7 postulates that the earthquake causes the stacked munitions to fall and may be punctured upon impact. Based on the coefficient of friction between pallets of munitions, a 0.3-g earthquake will likely cause some stacked munitions to fall and a 0.5-g earthquake will cause a large number to fall. The highest stacked munitions in an igloo can potentially fall 6 ft. The munition failure threshold data indicate that all palletized munitions and bulk containers can survive the impact of a drop from this height but could be punctured if they were to land on a probe which was sufficiently sharp and rigid. For this analysis a 0.3-g earthquake was assumed to cause 25% of the stacked pallets to fall while a 0.5-g earthquake will cause 100% of the stacked pallets to fall. The number of pallets which have the potential of impacting a probe was estimated for each munition type based on (1) how the pallets are stacked and (2) the floor area available for the pallets to fall. The calculation details are provided in Ref. 5-2.

The analysis of the presence of a probe in the igloo has indicated that it is unlikely that there is a probe inside the igloo that is sufficiently rigid and sharp to damage a munition. Table 5-10 provides the earthquake frequency data for each of the eight sites and the puncture probability of a munition type given a 6-ft drop.

Sequence SL22 involves the detonation of burstered munitions resulting from an earthquake-induced fall. The probability of a munition detonating from a 6-ft drop is estimated using the same approach discussed for detonations due to impact by wind-generated missiles.

5.2.4.2. Warehouses. The event tree describing release scenarios resulting from earthquake-induced accidents in warehouses is shown in Fig. 5-6. The event tree applies to the long-term storage warehouses at

TABLE 5-10
DATA BASE FOR ANALYSIS OF EARTHQUAKE-INDUCED AGENT RELEASE IN THE STORAGE IGLOOS

	Map Area 5 Site: TEAD	Map Area 2 Site: ANAD, LBAD, PBA, UMDA, and PUDA
Earthquake frequency (/yr) at		
0.3 to 0.5 g (F_1)	6.0E-4	1.9E-5
>0.5 g (F_2)	1.0E-4	6.0E-6
Probability stacked pallets will fall at		
0.3 to 0.5 g (P_1)	0.25	0.25
>0.5 g (P_2)	1.0	1.0

	Number of Munitions Falling At	
Munition Type	(N_1) 0.3 to 0.5 g	(N_2) >0.5 g
Bomb	3	11
105-mm cartridge	5	20
4.2-in. mortar	5	18
Ton container	6	22
Mine	4	14
Projectile	11	46
Rocket	5	20
Spray tank	N/A	N/A

SL7 (accident frequency) = $(F_1 * P_1 * N_1) + (F_2 * P_2 * N_2)$

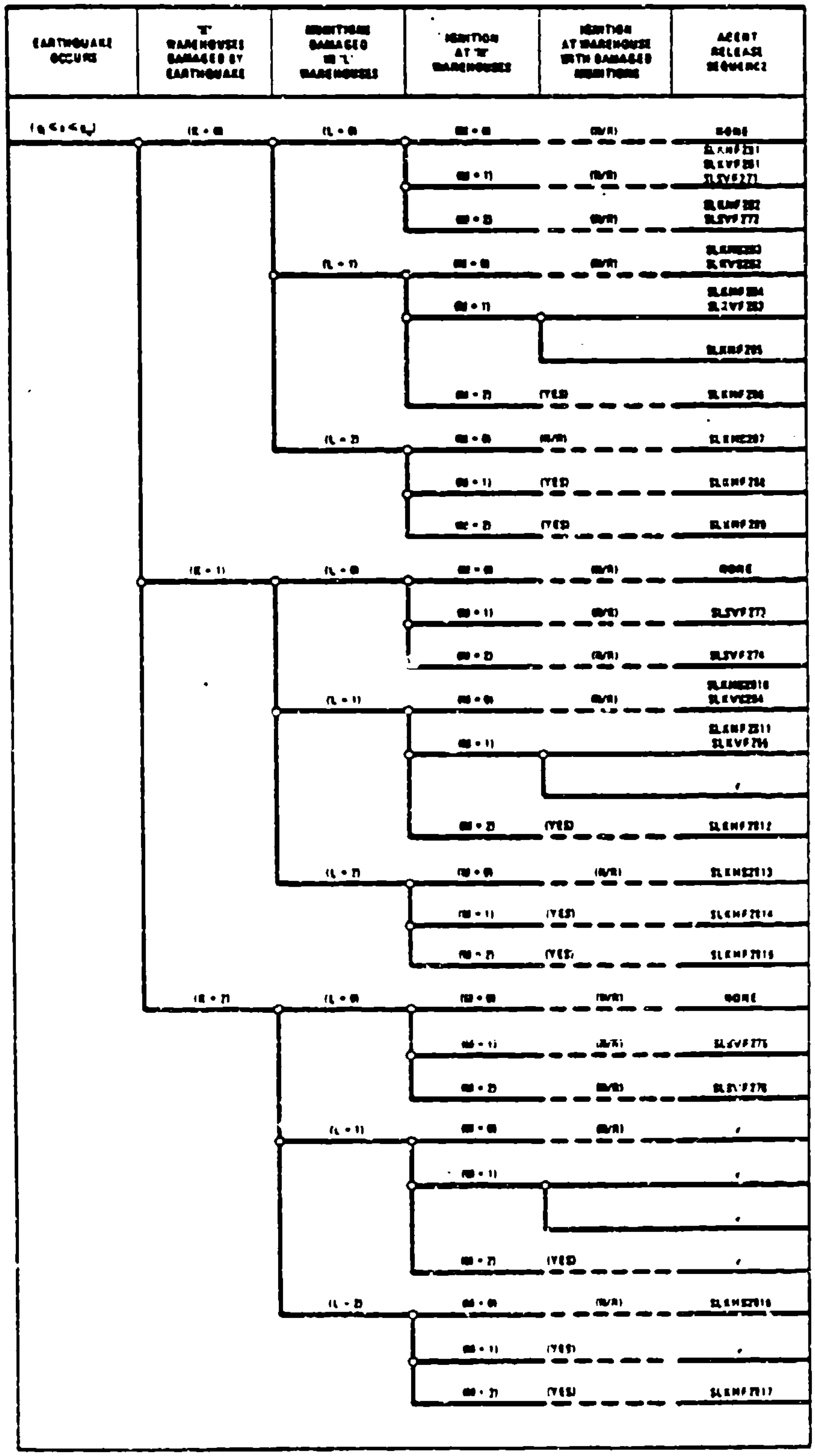

Fig. 5-6. Earthquake-induced releases from the warehouses

TEAD, NAAP, and UMDA. Spray tanks are stored at the two warehouses at TEAD. Ton containers are stored at NAAP in one warehouse and at UMDA in two adjacent warehouses.

Accident sequences describing releases from long-term storage warehouses are given in Table 5-11. Sequence designations are SLxxx26x for the NAAP warehouse, SLxxx27x for the TEAD warehouses, and SLxxx28x for the warehouses at UMDA. The accident sequence designations are also shown on the event tree in Fig. 5-6. For those accident sequences where no agent release occurs, the release sequence is labeled "None." Those release sequences whose frequency is below 1.0×10^{-10} for all sites have been labeled with an "F" in the event tree. The events modeled in Fig. 5-6 are discussed below:

1. <u>Earthquake Occurs</u>. The initiating event (Event 1) in Fig. 5-6 is earthquake occurrence. To simplify the event tree evaluation, Event 1 further restricts the earthquake intensity to an acceleration range from g_l (0.15 to 0.2 g) to g_u (7.7 g). Seven ranges are considered:

   a. 0.15 to 0.2 g.
   b. 0.2 to 0.3 g.
   c. 0.3 to 0.4 g.
   d. 0.4 to 0.5 g.
   e. 0.5 to 0.6 g.
   f. 0.6 to 0.7 g.
   g. Greater than 0.7 g.

   Earthquakes below 0.15 g are not considered in the analysis because the damage probabilities associated with such tremors are negligibly small. Detailed examination of seismic ranges above 0.7 g is unnecessary because earthquakes above 0.7 g have a probability of almost 1.0 of causing damage.

TABLE 5-11
EARTHQUAKE-INDUCED ACCIDENTS IN WAREHOUSES

Agent Release Sequence	Median Frequency (per Year)
SLSVF 271	2.7E-04
SLSVF 272	8.3E-06
SLSVF 273	3.1E-05
SLSVF 274	1.9E-06
SLSVF 275	7.0E-07
SLSVF 276	4.8E-08
SLKVF 261	1.1E-05
SLKVS 262	9.5E-07
SLKVF 263	1.1E-09
SLKVS 264	3.3E-04
SLKVF 265	1.4E-04
SLKHF 281	4.8E-07
SLKHF 282	6.3E-05
SLKHS 283	1.9E-07
SLKHF 284	3.1E-10
SLKHF 285	3.1E-10
SLKHF 286	F
SLKHS 287	8.5E-10
SLKHF 288	F
SLKHF 289	F
SLKHS 2810	1.4E-05
SLKHF 2811	2.9E-05
SLKHF 2812	1.2E-07
SLKHS 2813	7.6E-08
SLKHF 2814	6.9E-08
SLKHF 2815	3.6E-10
SLKHS 2816	5.6E-05
SLKHF 2817	1.1E-05

NOTE: F denotes extremely low frequency.

The initiating event frequency at each site is the site-specific frequency at which earthquakes in the range gl to gu occur.

2. "K" Warehouses Damaged by Earthquake. Warehouse damage is defined as structural collapse. This is the only failure mode of interest because it will crush stored ton containers. Although less severe damage can result from an earthquake, it was screened in quantifying the Event 2 probability because it does not induce ton container failure.

   Three damage combinations are considered in Event 2:

   a. No warehouses are damaged (K = 0).
   b. Only one warehouse is damaged (K = 1).
   c. Both warehouses are damaged (K = 2).

   Tracking these three probabilities is necessary in order to estimate the agent release source term. Note that since there is only one warehouse at NAAP, the probability that K = 2 is zero for that site.

   Event 2 damage probabilities are based upon a generic study of damage to structures designed to the Uniform Building Code.

3. Munitions Damaged in "L" Warehouses. Event 3 addresses whether the earthquake causes an agent release from the stored munitions. Two failure modes are analyzed: puncture and crushing.

   Only ton containers are subject to these failures. Spray tanks are in overpacks which protect them from crush forces. Furthermore, they are not stacked while in storage, hence they cannot be punctured.

Three damage combinations are considered in Event 3:

a. No agent releases result from the earthquake (L = 0).

b. The earthquake causes an agent release in one warehouse (L = 1).

c. The earthquake causes an agent release in both warehouses (L = 2).

The puncture probability is the probability that at least one ton container falls and strikes a probe of sufficient size and density to penetrate it. The probability that ton containers are crushed is correlated to warehouse damage. If K is 0, 1, or 2 in Event 2, then ton containers in none, 1, or 2 warehouses are crushed, respectively. Since the NAAP site has only one warehouse, the probability that L = 2 is zero for that site. In addition, since only spray tanks are stored in the TEAD warehouses, L can only be zero at that site.

4. Ignition at "M" Warehouses. Seismically initiated fires are an important consideration because they influence agent dispersion and can thermally fail agent containers. This second aspect is particularly important at TEAD because fire damage is the only spray tank container failure mode.

Electrical fires are the only concern in warehouses. The three conditions necessary for an electrical fire are:

a. An electrical fault capable of causing arcing.
b. A supply of electric power to sustain the arc.
c. Contact with an ignition source.

Including this second condition in the fire ignition probability calculation is important because available data indicate that offsite power can be lost at a relatively low seismic intensity.

Condition three considers both the agent and wood dunnage assemblies as possible ignition sources in the warehouses. If ton containers have been damaged by either crush or puncture, the probability of igniting spilled agent given an electrical arc has occurred is essentially unity. If no munition damage has occurred, the probability of ignition is represented as the ratio of exposed wood surface area to the total area of the warehouse.

Similar to previous events, Event 4 addresses how many warehouses experience ignition.

5. <u>Ignition at Warehouse With Damaged Munitions</u>. If the earthquake only damages the containers stored in one warehouse and ignition occurs at only one warehouse, it is necessary to discern whether the fire is in the warehouse with the damaged containers. If the fire is in the same warehouse as the damaged containers, thermal failure and the subsequent release of agent from the second warehouse is averted. However, if the damaged containers and fire are in different warehouses, then the agent release source term will be increased.

Suppression of fires has a negligible probability since the warehouses have no fire alarms nor automatic fire suppression systems. For this reason it is not considered in the warehouse analysis.

5.2.5. Lightning

Munitions stored in igloos and warehouses are protected from lightning. Hence, only ton containers stored outdoors at APG, PBA, and TEAD may be susceptible to lightning strikes. No event tree model has been developed for this scenario. Basically, if sufficiently energetic lightning strikes a ton container, the container will be breached and agent will spill to the ground.

A lightning strike density for the contiguous United States was previously determined (Ref. 5-12) based on the correlation developed from the duration of thunderstorms. Based on this empirical correlation, the frequency (events/yr-km^2) for the different storage locations has been determined, as shown in Table 4-7.

Using conservative assumptions, a threshold lightning energy required to burn through the ton container wall was found to be proportional to the fourth power of the wall thickness as described in the calculation sheets (Ref. 5-2). Neglecting corrosion thinning of the container wall, the maximum value of failure frequency for each cluster of 15 ton containers at PBA is 5.1×10^{-10}, as shown in Table 5-12.

The results indicate that the threshold lightning energy required to burn through the container wall is a strong function of wall thickness. In order to assess the sensitivity of the failure frequency to corrosion, a probability density function for wall thickness was derived by conservatively assuming that one ton container stored outdoors has a leak through its wall. This is a conservative assumption since no wall leak has been reported. This probability density function for wall thickness is used in conjunction with the lightning energy requirements to calculate the failure frequency of a cluster of 21 containers at the different sites. As expected for the PBA site, the failure probability is increased by approximately 55 from the previous value of 5.1×10^{-10}.

TABLE 5-12
SITE-SPECIFIC LIGHTING STRIKE INFORMATION

Name of Site	Ground Density [1] Event/Yr/km^2 N_1	Projected Area for Each Cluster (21 Container) (km)	Failure Probability Event/Yr-Cluster No Corrosion Effect	Failure Probability Event/Yr-Cluster Corrosion Effect
Aberdeen Proving Ground (APG)	3	2.5×10^{-3}	1.4×10^{-10}	7.65×10^{-9}
Anniston Army Deport (ANAD)	9	2.5×10^{-3}	--	
Laxington - Blue Grass Army Depot (LBAD)	9	2.5×10^{-3}	--	
Newport Army Ammunition Depot (NAAP)	5	2.5×10^{-3}	--	
Pine Bluff Arsenal (PBA)	11	2.5×10^{-3}	5.1×10^{-10}	2.8×10^{-8}
Pueblo Depot Activity (PUDA)	4	2.5×10^{-3}	--	
Tooele Army Deport (TEAD)	3	2.5×10^{-3}	1.4×10^{-10}	7.65×10^{-9}
Umatilla Depot Activity (UMDA)	2	2.5×10^{-3}	--	

If all other agent release scenarios have frequencies that are below this bounding value, then the extent of container corrosion must be investigated. However, if other scenarios involving comparable or larger amounts of agent release also have much higher frequencies than the bounding value for the lightning initiated release, then lightning release scenarios can be ignored. This is true for aircraft crash accidents which lead to much larger releases and also higher frequencies for some sites.

5.2.6. Floods

During a flood, materials such as lumber, crates, storage tanks, and other lightweight containers may be carried away by flood flows and cause damage to downstream structures. Water velocities during floods depend largely on the size and shape of the cross sections, conditions of the stream, and the slope bed, all of which vary on different streams and at different locations. In the upper reaches of a flood basin, main channel flows could be as high as 14 ft/s, but typical overbank flow is less than 2 ft/s (Ref. 5-13).

Munitions stored in igloos and warehouses are considered protected against flood-generated projectiles. The only munition stored outdoors are mustard-filled ton containers (APG, PBA, and TEAD).

The puncture equation is as follows:

$$V_m^2 = \{64\ (672\ DT)^{3/2}\}/W \quad , \tag{5-5}$$

where D = probe diameter (in.),
T = wall thickness to be punctured (in.),
W = weight of projectile (i.e., moving object) (lb),
V_m = velocity of projectile (ft/s).

The wall thickness of the ton container is 0.41 in. Assuming the smallest probe size is 0.8-in. in diameter,

$$V_m^2 (W) = (64)(672\ DT)^{3/2} = 217,335 \quad . \tag{5-6}$$

For puncture, the following conditions must be met:

V_m (ft/s)	W (lb)
1	217,335
2	53,334
6	6,037
10	2,173
14	1,108

A credible flood-generated projectile is assumed to be a light, steel tank with a rigidly attached 0.8-in. diameter probe. This could be a water storage tank or a gasoline tank, using a tank height to diameter ratio of 1.2 and a wall thickness of 0.25 in. Table 5-13 presents the data developed for steel tanks. Tanks larger than 10 ft in diameter would not be credible except in main channel flows. Thus, typical overbank flows, i.e., 2 ft/s, would not produce puncture.

Puncture could be initiated by using an extreme overbank velocity of 6.13 ft/s combined with a 10-ft diameter floating tank with a rigidly attached 0.8-in. probe. The probability of a 6.13 ft/s overbank velocity is estimated to be less than 10%. This condition will be designated as the reference flood-generated projectile.

The probability of puncture of a single ton container from the reference single floating tank condition is as follows:

$$P_F = L_p \times T_p \times P_p \quad , \tag{5-7}$$

TABLE 5-13
PROBABLE SIZE DISTRIBUTION FOR STEEL TANKS

D Diameter (ft)	1.2D Height (ft)	$57.67D^2$ Weight (lb)	$5.3407D^2$ Surface Area (ft^2)
2	2.4	231	21.36
4	4.8	923	84.45
6	7.2	2076	192.0
8	9.6	3690	342.0
10	12.0	5767	534.0

where L_p = location probability, i.e., the probability that the probe attached to the floating tank is pointing towards the ton container wall at the moment of collision,

T_p = target probability, i.e., the probability that the tank collides with the ton container,

P_p = probability of probe being present.

L_p can be approximated by the ratio of total surface area to the effective surface position. Assuming that the probe must be within a 1 ft^2 location, then:

$$L_p = 1/(7.06)^2\ (5.3407) = 0.0038 \quad . \tag{5-8}$$

T_p can be approximated by assuming a flood channel width at the point of collision and comparing that to the length of a ton container (82 in.). Using a three-mile wide channel, which is conservative for a typical flood, then:

$$T_p = 82/\{(5280)\ (12)\ (3)\} = 0.00043 \text{ or } 0.0043 \tag{5-9}$$

for the total width of 10 containers.

P_p is estimated to be 1×10^{-3}. Thus the probability of a reference tank hitting and rupturing a ton container is

$$P_F = (0.0038)\ (0.0043)\ (0.001) = 1.6 \times 10^{-8} \quad . \tag{5-10}$$

It would seem reasonable from the flood basin size to assume no more than one reference floating projectile per flood and the flood reoccurrence to be greater than 100 years. In addition, the probability of a 6 ft/s overbank velocity is estimated as 10%. Thus, the probability of rupture is approximately 1.63×10^{-11}/yr.

Thus, based on the above calculations this scenario can be screened out on the basis of the frequency criterion of less than 1.0×10^{-10}/yr.

5.3. SPECIAL HANDLING ACTIVITIES

5.3.1. Leaking Munitions

Several scenarios were identified that specifically address the leakage of stored munitions and the accidents that could occur in the process of isolating leaking munitions which could aggravate the existing situation. The event trees are shown in Figs. 5-7 and 5-8.

Sequence SL1 addresses the possibility that a munition could leak from the time the periodic inspection has been performed until the next periodic inspection. It is assumed that the leaking munition will be detected at the time the next inspection is made. For all sites, except at APG, the inspections are assumed to be performed quarterly (90 days). At APG, the ton containers are inspected daily. No event tree was developed for this scenario since it is represented by a single event failure.

Sequences SL2 and SL9 address accidents related to the movements of munitions for inspection or isolation of leakers. The forklift tine puncture or drop of munition was determined to be largely due to human error. The quantification of these events required a detailed human reliability study (Ref. 5-14). Essentially a task analysis was performed to identify those errors that could potentially impact agent release probabilities. Available data was used to quantify the probabilities of some of these errors and extrapolations were made from these fixed data to quantify the remainder.

Isolation of leaking rockets require special tasks. The leaking rockets are isolated in the storage igloo at the original location, where the pallet containing the leaking rocket is unpacked. Only those truck that will carry it to an igloo reserved for leaking munitions (Ref. 5-1). The analysis assumes that the same procedure is followed

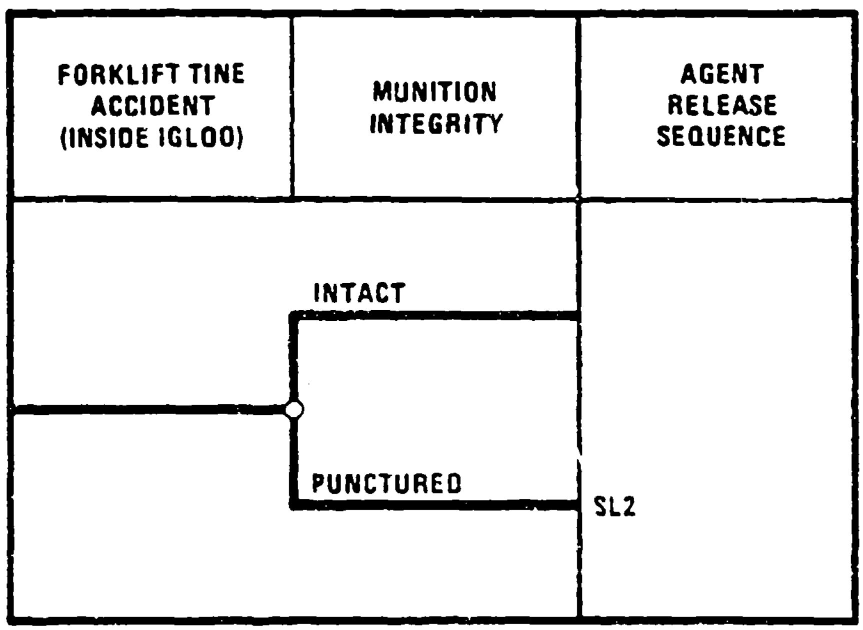

Fig. 5-7. Munition punctured by forklift tine during leaker - handling activities

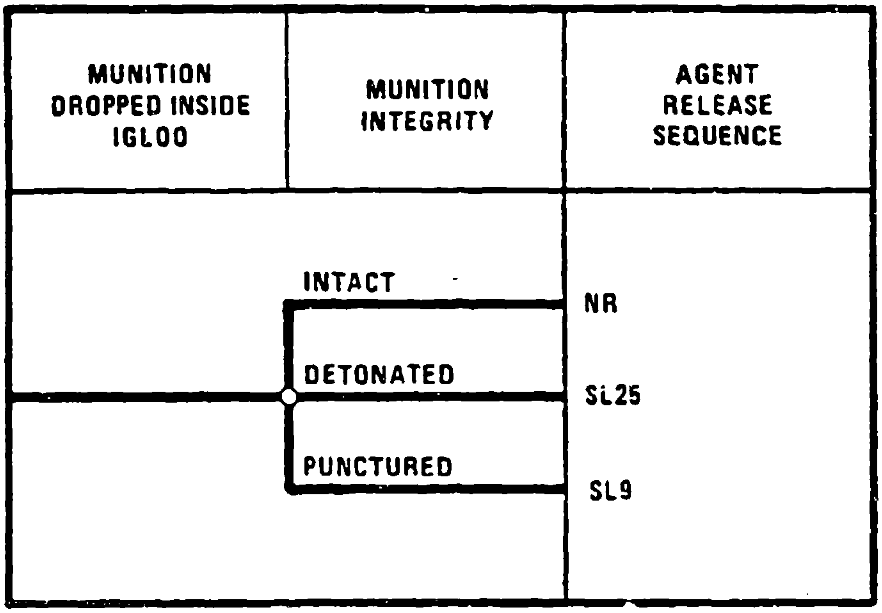

Fig. 5-8. Munition dropped during leaker isolation operation

for isolating other leaking munitions, except that overpacks (other than PIGs) are used.

Three types of operator errors related to leaker isolation were identified in the task analysis: (1) puncturing a munition with a forklift tine, (2) dropping a munition or pallet from a forklift, and (3) dropping a single munition while hand-carrying it. These errors are discussed in more detail below.

1. Puncturing a munition with a forklift tine might occur any time a munition or pallet is approached with a forklift tine. Puncture probability is a function of the human error that results in impact of the tine with the munition and of the vulnerability of the munition to such an impact.

2. Dropping a munition or a pallet from a forklift could occur any time a forklift is carrying a load. This action could be caused by operating the forklift in a way that causes the load to fall or by loading the forklift such that the load is misaligned or the weight distribution within the pallet or munition is unbalanced. It could also result from the pallet's getting caught on and pulled off by something it runs into. Sudden acceleration or deceleration, sharp turns, high-speed operation, or operation over uneven ground could all be contributors to munition drops.

3. Dropping a munition while hand-carrying it might occur any time the munition is picked up, put down, or carried without a forklift or other lifting device. It could be caused by the operator's falling as he carries the munition or by the munition's slipping from his grasp.

A previously identified scenario involving the improper replacement of a corroded valve or plug in a ton container (Sequence SL16, Ref. 5-15), has been deleted in the present evaluation. It is expected that ton containers with GB will require that their valves be replaced before 1991. The human reliability analysis (see Appendix J) concluded that this event has a low frequency of occurrence. Furthermore, the amount of mustard or VX that could be dispersed to the atmosphere from a valve or plug replacement operation is insignificant.

Table 5-14 presents the data used to evaluate the accident frequencies for the scenarios addressed above. The frequency of scenario SL1 was derived by determining the leakage rate for each munition type based on the leaker data at each site and the total munition inventory at each site. Since the two parameters are classified information, they will be presented and discussed further in a classified appendix.

5.3.2. Human-Error Probability Estimation

The human-error probabilities were quantified. Using the approach to human-error estimation described in NUREG/CR-1278 (Ref. 5-19). Probabilities of human errors were estimated based on several performance-shaping factors such as munition configuration, handling operation, clothing level, and crew size. These factors are identified in the discussions that follow on the derivations of each estimate. Table 5-15 lists the error probabilities estimated for puncturing or dropping a munition based on each of these factors.

1. Puncturing a munition. The basis for the error estimates is taken from Section 4.4.2 of Reference 5-1 (pps. 4.4-26). This reference gives 4E-5 as a data-based estimate of the probability of handling errors using forklifts for the rocket stockpile. This is an estimate of the likelihood of an error in forklift operation that potentially could lead to a warhead rupture while attempting to isolate a leaking rocket inside the storage igloo.

TABLE 5-14
DATA BASE FOR ANALYSIS OF SEQUENCES SL1, SL2, AND SL9

Event	Frequency of Probability	Reference
Munition develops a leak during storage (Scenario SL1):		
Bomb (TEAD)	7.5E-5 per year	Ref. 5-16
(UMDA)	4.5E-4 per year	
4.2-in. mortar (ANAD)	2.8E-7 per year	
(PUDA)	1.0E-6 per year	
(TEAD)	7.0E-6 per year	
105-mm cartridge (ANAD)	2.8E-7 per year	
(PUDA)	1.0E-6 per year	
(TEAD)	7.0E-6 per year	
Ton container		
Mine (ANAD)	9.0E-6 per year	
(PBA)	1.1E-6 per year	
(TEAD)	2.5E-4 per year	
(UMDA)	3.1E-4 per year	
Projectile (ANAD)	4.9E-6 per year	
(LBAD)	9.3E-6 per year	
(PUDA)	5.0E-6 per year	
(TEAD)	8.1E-5 per year	
(UMDA)	6.2E-5 per year	
Rocket (ANAD)	6.1E-5 per year	
(LBAD)	4.3E-5 per year	
(PBA)	9.1E-7 per year	
(TEAD)	1.3E-3 per year	
(UMDA)	1.8E-4 per year	
Spray tank	9.8E-5 per year	
Forklift tine accident (SL2)	1.0E-4 per operator	Ref. 5-15
Munition puncture given tine accident:		
Bomb	1.29E-2	Ref. 5-2
4.2-in. mortar	3.68E-2	
105-mm cartridge	8.90E-3	
Mine	7.07E-2	

TABLE 5-14 (Continued)

Event	Frequency of Probability	Reference
Projectile	5.00E-2	
Rocket	2.63E-1	
Spray tank	1.53E-2	
Munition dropped during leaker isolation (SL9):		
Pallet and bulk (B, S)	3.0E-4	Human reliability
Single (C, D, M, P, Q, R)	6.0E-4	Analysis (Ref. 5-15)
Ton container (K)	3.0E-5	
Munition punctured given drop:		
Bomb (pallet)	4.72E-4	Ref. 5-2
(single)	1.62E-4	
4.2-in. mortar (pallet)	1.24E-4	
(single)	0.0	
105-mm cartridge (pallet)	2.71E-5	
(single)	0.0	
Ton container	1.55E-3	
Mine (pallet)	9.27E-5	
(single)	4.08E-5	
Projectile (pallet or single)	0.0	
Munition detonates given 6 ft drop	1.6E-8/munition	Ref. 5-2

TABLE 5-15
HUMAN ERROR PROBABILITIES PER HANDLING OPERATION

Error Type For Munition Configuration	Handling Operation for Clothing Type: Level A or DPE — Hand Carry[a]	Level A or DPE — Forklift	Levels B, C, and D (Mask, Gloves, and Boots) — Hand Carry[a]	Levels B, C, and D (Mask, Gloves, and Boots) — Forklift	Levels E and F (Street Clothes, Mask Slung) — Hand Carry[a]	Levels E and F (Street Clothes, Mask Slung) — Forklift
Tine Carried						
Drop	6.0×10^{-4}	3.0×10^{-4}	3.0×10^{-4}	1.5×10^{-4}	6.0×10^{-5}	3.0×10^{-5}
Puncture	NA	1.0×10^{-4}	NA	5.0×10^{-5}	NA	1.0×10^{-5}
Beam Carried						
Drop	NA	3.0×10^{-5}	NA	1.5×10^{-5}	NA	3.0×10^{-6}
Puncture	NA	NA	NA	NA	NA	NA

(a) Hand-carry operations involve one weapon at a time.

That estimate is based on conditions that do not entirely represent those assumed by this study; namely, that a three-man crew will perform all forklift operations. In this study, it is assumed that a two-man crew will perform all forklift operations--one driving the forklift and one guiding forklift and munition position from the ground. This means that the data-based estimate may not represent the probability of forklift-handling errors expected under actual conditions. Therefore, this estimate was revised to 1×10^{-4} to account for a smaller crew. The revised estimate of 1×10^{-4} is the probability that one or both members of a two-man crew will err such that the forklift tine is in a position to puncture a munition. (This puncture probability applies to those cases in which forklift tines are used to lift munitions; it includes palletized munitions and spray tanks in overpacks.)

Another difference is that the original estimate from Reference 5-1 (4×10^{-5}) was based on operations with leaking rockets. This meant that it assumes that the crew is wearing Level A protective clothing. If the same forklift operations are performed in less strenuous circumstances (i.e., if a lower level of protective clothing is worn), the error probability estimate can be lowered. Here, it has been lowered to 5×10^{-5} for the case of the operators' wearing partial protection (masks, gloves, and boots) and to 1×10^{-5} for the case of their wearing minimal protection (street clothes, with masks slung).

2. Dropping a munition. For palletized munitions and spray tanks in their overpacks, human-caused drops from forklifts are judged to be three times as likely as punctures caused by operating the same kind of forklift. The error-probability estimates are 3×10^{-4}, 1.5×10^{-5}, and 3×10^{-5} for dropping

a munition from a forklift tine when wearing Level A, Level C, or Level F protective clothing, respectively.

Because of unwieldy pallet and overpacked spray tank loads and because it is assumed that forklift-tine loads are likely to be carried at higher speeds than are forklift-beam loads, the likelihood of a TC's or other beam-carried load's being dropped because of human error is judged to be an order of magnitude lower than that of a tine-carried load's being dropped. These are estimated to be 3×10^{-5}, 1.5×10^{-6}, and 3×10^{-6} for protective clothing Levels A, C, and F, respectively.

For hand-carrying munitions, munition drops are estimated to be twice as likely as drops of tine-carried loads from forklifts. The estimated probabilities of dropping a hand-carried munition when wearing Levels A, C, and F protective clothing are 6×10^{-4}, 3×10^{-4}, and 6×10^{-5}, respectively. (Loads carried by forklift beams are never hand-carried.)

These probability estimates are the likelihood of an error per handling operation. A single forklift operation may involve a single munition such as a spray tank or as many as 48 weapons on a pallet, while a single hand-carry operation will always involve only a single munition.

5.3.3. Surveillance and Maintenance Activities

For the continued storage option, additional handling accident scenarios were identified which relate to the planned surveillance and maintenance of munitions over the 25-yr continued storage period. According to information provided to GA by the U.S. Army, all currently stored munitions will be taken out of their present storage locations and brought to a maintenance facility for inspection. The risk analysis addresses on the accidents that could occur during the movement of these munitions from storage to the maintenance facility and back to storage. Table 5-16 shows the number of times each munition type will be moved to the maintenance facility for surveillance. Note that not all munition types are shown in this list. It is therefore assumed that the handling and transportation accident scenarios will not apply to those munitions not listed in Table 5-16. Table 5-17 lists the handling-related sequences that were identified. Sequences SH1 through SH7 involve surveillance and scenarios SH8 through SH12 involve pallet inspection. For pallet inspection, the procedure is to move the pallet to the igloo apron and inspect the pallet for any degradation visually. It is assumed that only electric forklifts will be used to move the pallets.

The analysis of these activities does not include the actual maintenance performed on the individual munitions. It is not clear what type of maintenance will be performed during this period. Furthermore, it may also be possible that the maintenance will be performed in-situ. Although the number of handling activities considered the movement of the munitions from their storage locations to a maintenance facility by truck, the accidents involving actual onsite transportation were not specifically analyzed. The results of the onsite transportation analysis for the Onsite Disposal Option (Ref. 5-19) are considered to apply here.

It is not yet clear if the Army will move the munitions in overpacks should it decide to choose the continued storage alternative. If the Army decides to put them in overpacks then the transportation risk analysis results for the onsite option directly apply. However, the

TABLE 5-16
MAINTENANCE AND SURVEILLANCE SCHEDULE

Munition	Number of Times Maintenance is Required For Next 25 yr
Cart., 105 mm, GB, M360	2 times
Proj., 155 mm, GB, M121/A1	2 times
Proj., 155 mm, H/HD, M110	Every 30 months
Proj., 155 mm, VX, M121A1	Every 8 yr (10% of inventory)
Proj., 155 mm, VX, M121A1	2 times (90% of inventory)
Proj., 8 in., VX, M426	Every 8 yr (14% of inventory)
Proj., 8 in., VX, M426	2 times (86% of inventory)
Proj., 8 in., GB, M426	Every 8 yr (15% of inventory)
Proj., 8 in., GB, M426	2 times (85% of inventory)
Bomb, GB, MK116MOD 0	2 times
Bomb, MK94	Every 8 yr
Bomb, GB, MC1	Every 8 yr (30% of inventory)
Bomb, GB, MC1	2 times (70% of inventory)
Ton containers, all agents	Once

Notes: No overpacks, except for the items currently stored in overpacks, will be used for onsite movement to the maintenance facility. This is equivalent to the current procedures. The distance for the truck moves between the storage area and the maintenance facility is site specific; and the approximate distance, if greater than one mile or one mile, should be used.

Surveillance: Over the next 25 yr, surveillance will handle approximately 2500 munitions per year for the next 25 yr. Operations consist of a forklift move of a pallet to igloo apron, inspections, and forklift move back into igloo. Both bombs and leakers may be moved inside the igloo, but quantitative estimates cannot be provided.

TABLE 5-17
HANDLING ACCIDENTS INVOLVING MUNITION SURVEILLANCE AND MAINTENANCE DURING CONTINUED STORAGE

SH1	Drop of pallet or container in storage area or maintenance facility during handling-related maintenance operations; munition punctured.
SH2	Forklift collision with short duration fire during movement in storage area or maintenance facility during handling-related maintenance operations.
SH3	Forklift tine accident during movement in storage area or maintenance facility during handling-related maintenance operations.
SH4	Forklift collision accident without fire in storage area or maintenance facility during handling-related maintenance operations.
SH5	Drop of munition during handling either in storage area or maintenance facility (during handling-related maintenance operations) leads to detonation.
SH6	Collision accident during handling either in storage area or maintenance facility (during handling-related maintenance operations) leads to detonation.
SH7	Collision accident during handling either in storage area or maintenance facility (during handling-related maintenance operations) with prolonged fire leads to thermal detonation or hydraulic explosion.
SH8	Munition pallet dropped during handling-related movement in and out of the igloo for pallet inspection munition punctured.

TABLE 5-17 (Continued)

SH9	Forklift tine accident during handling-related movement in and out of the igloo for pallet inspection no detonation.
SH10	Forklift collision accident during handling-related movement in and out of the igloo for pallet inspection (no fire since electric forklifts are used); no detonation.
SH11	Munition pallet dropped during handling-related movement in and out of the igloo for pallet inspection; munition detonated.
SH12	Forklift collision accident during handling-related movement in and out of the igloo for pallet inspection (no fire since electric forklifts are used); munition detonated.

transportation risk for movement of munitions even without overpacks should not differ significantly for the following reasons:

1. The protection from impact provided by most munition casings are at least as strong as the currently designed onsite package.

2. Most munition casings provide as much protection from crush as the package.

3. The possibility of a fire longer than 10 min has been eliminated by an administrative requirement of limiting the amount fuel carried by a truck to less than 65 gallons. Therefore, even if the package provides a 15-min protection from an all engulfing fire, there will be no difference in the risk results for packaged or unpackaged munitions.

4. Thin-walled munitions such as the 4.2-in mortar projectiles, mines and rockets apparently will not be taken to a maintenance facility for inspections since they are not listed in Table 5-16. The package designed for onsite transportation of munitions provides additional protection for these munitions. For thick-walled munitions such as the projectiles, the difference in risk of whether they are in or out of a package is negligible.

Table 5-18 presents the data used to evaluate the accident frequencies for the scenarios addressed above. The frequency of scenario SL1 was derived by determining the leakage rate for each munition type based on the leaker data at each site and the total munition inventory at each site. Since the two parameters are classified information, they will be presented and discussed further in a classified appendix to this report (Appendix H).

TABLE 5-18
DATA BASE FOR LEAKERS IN STORAGE

Event		Frequency or Probability	Reference
Munition develops a leak during storage (Scenario SL1):			
Bomb	(TEAD)	7.5E-5 per yr	Ref. 5-16
	(UMDA)	4.5E-4 per yr	
4.2-in. mortar	(ANAD)	2.8E-7 per yr	
	(PUDA)	1.0E-6 per yr	
	(TEAD)	7.0E-6 per yr	
105-mm cartridge	(ANAD)	2.8E-7 per yr	
	(PUDA)	1.0E-6 per yr	
	(TEAD)	7.0E-6 per yr	
Ton container		5.9E-6 per yr	
Mine	(ANAD)	9.0E-6 per yr	
	(PBA)	1.1E-6 per yr	
	(TEAD)	2.5E-4 per yr	
	(UMDA)	3.1E-4 per yr	
Projectile	(ANAD)	4.9E-6 per yr	
	(LBAD)	9.3E-6 per yr	
	(PUDA)	5.0E-6 per yr	
	(TEAD)	8.1E-5 per yr	
	(UMDA)	6.2E-5 per yr	
Rocket	(ANAD)	6.1E-5 per yr	
	(LBAD)	4.3E-5 per yr	
	(PBA)	9.1E-7 per yr	
	(TEAD)	1.3E-3 per yr	
	(UMDA)	1.8E-4 per yr	
Spray tank		9.8E-5 per yr	
Forklift tine accident (SL2)		1.0E-4 per oper.	Ref. 5-15
Munition punctured given tine accident:			
Bomb		1.29E-2	Ref. 5-2
4.2-in. mortar		3.68E-2	
105-mm cartridge		8.90E-3	
Mine		7.07E-2	
Projectile		5.00E-2	

TABLE 5-18 (Continued)

Event	Frequency or Probability	Reference
Rocket	2.63E-1	
Spray Tank	1.53E-2	
Munition dropped during leaker isolation (SL9):		
Pallet and bulk (B, S)	3.0E-4	Human Reliability Analysis (Ref. 5-15)
Single (C,D,M,P,Q,R)	6.0E-4	
Ton container (K)	3.0E-5	
Munition punctured given drop:		
Bomb (pallet)	4.72E-4	Ref. 5-2
(single)	1.62E-4	
4.2-in. mortar (pallet)	1.24E-4	
(single)	0.0	
105-mm cartridge (pallet)	2.71E-5	
(single)	0.0	
Ton container	1.55E-3	
Mine (pallet)	9.27E-5	
(single)	4.08E-5	
Projectile (pallet or single)	0.0	
Munition detonates given drop:	1.6E-8/munition	Ref. 5-2
Forklift collision leads to drop of munitions	4.3E-6/oper.	Ref. 5-12 and Ref. 5-2
Collision results in fire	0.0725	Ref. 5-12
Fire contained:		
Burstered (4 min)	0.5	Engineering judgement
Nonburstered (30 min)	1.00	Fuel will be limited so as limit fire to less than 10 min

5.4. SCENARIO QUANTIFICATION

Tables 5-19 and 5-20 present the results of the accident sequence frequency analysis for all the storage scenarios discussed previously except those which were initially screened (i.e., SL10, SL11, SL12, SL13, and SL14). From the results it is evident that the following sequences could be screened out (from all eight sites) further based on the 1.0 x 10^{-10}/yr criterion:

SL17 - Large aircraft direct crash; fire contained in 30 min.

SL21 - Large aircraft indirect crash; fire contained in 30 min.

SL23 - Tornado-generated missiles cause munition detonation upon impact.

Since handling-related accidents are given in terms of events per munition operation, no screening can be performed without divulging classified information.

Table 5-21 presents the results of the accident scenarios related to the planned surveillance and maintenance of munitions over the 25-yr continued storage period.

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TABLE 5-19
FREQUENCIES OF STORAGE ACCIDENT SEQUENCES
(SL1 THROUGH SL25)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SL1 - Munition develops a leak during the between-inspections period.																	
SLRGC	1	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	7.5E-05	1.0E+01	4.5E-04	1.0E+01
SLOHC	1	2.0E-07	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	1.0E-06	1.0E+01	7.0E-06	1.0E+01	N/A	-
SLCGC	1	2.0E-07	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	7.0E-06	1.0E+01	N/A	-
SLCHC	1	2.8E-07	1.0E+01	N/A	-	N/A	-	N/R	-	N/A	-	1.0E-06	1.0E+01	N/A	-	N/A	-
SL1GC (IGL)	1	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.9E-04	1.0E+01	N/A	-
SLHC (IGL)	1	5.9E-06	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLHS (OPEN)	1	N/A	-	N/A	-	N/A	-	N/A	-	5.9E-06	1.0E+01	N/A	-	5.9E-06	1.0E+01	N/A	-
SLHS (OPEN)	1	N/A	-	5.9E-06	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLHC (WH)	1	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	5.9E-06	1.0E+01
SLVC (IGL)	1	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	5.9E-06	1.0E+01	N/A	-
SLVC (WH)	1	N/A	-	N/A	-	N/A	-	5.9E-06	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-
SLMVC	1	9.0E-06	1.0E+01	N/A	-	N/A	-	N/A	-	1.1E-06	1.0E+01	N/A	-	2.5E-04	1.0E+01	3.1E-04	1.0E+01
SLPGC	1	4.9E-06	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	8.1E-05	1.0E+01	6.2E-05	1.0E+01
SLFHC	1	4.9E-06	1.0E+01	N/A	-	9.3E-06	1.0E+01	N/A	-	N/A	-	5.0E-06	1.0E+01	8.1E-05	1.0E+01	N/A	-
SLPVC	1	4.9E-06	1.0E+01	N/A	-	9.3E-06	1.0E+01	N/A	-	N/A	-	N/A	-	8.1E-05	1.0E+01	6.2E-05	1.0E+01
SLQGC	1	4.9E-06	1.0E+01	N/A	-	9.3E-06	1.0E+01	N/A	-	N/A	-	N/A	-	8.1E-05	1.0E+01	6.2E-05	1.0E+01
SLQVC	1	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	8.1E-05	1.0E+01	6.2E-05	1.0E+01
SLRGC	1	6.1E-05	1.0E+01	N/A	-	4.3E-05	1.0E+01	N/A	-	9.1E-07	1.0E+01	N/A	-	1.3E-03	1.0E+01	1.8E-04	1.0E+01
SLRVC	1	6.1E-05	1.0E+01	N/A	-	4.3E-05	1.0E+01	N/A	-	9.1E-07	1.0E+01	N/A	-	1.3E-03	1.0E+01	1.8E-04	1.0E+01
SLSVC	1	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.8E-05	1.0E+01
SLSVC (WH)	1	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.0E-05	1.0E+01	N/A	-
SL2 - Munition punctured by forklift tine during leaker handling activities.																	
SLRGC	2	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	5.2E-06	1.3E+01	5.2E-06	1.3E+01
SLOHC	2	4.4E-05	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	4.4E-05	1.3E+01	4.4E-05	1.3E+01	N/A	-
SLCGC	2	1.1E-05	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.1E-05	1.3E+01	N/A	-
SLCHC	2	1.1E-05	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	1.1E-05	1.3E+01	N/A	-	N/A	-
SLFGC	2	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-

See notes at end of table.

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TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	NAAP FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	UMAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SL1HC	2	0.0E+00	-	0.0E+00	-	N/A	-	N/A	-	0.0E+00		N/A	-	0.0E+00	-	0.0E+00	-
SL1VC	2	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-	N/A	-	0.0E+00	-	N/A	-
SL1MVC	2	8.5E-05	1.3E+01	N/A		N/A	-	N/A	-	8.5E-05	1.3E+01	N/A	-	8.5E-05	1.3E+01	8.5E-05	1.3E+01
SLFGC	2	6.0E-05	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	6.0E-05	1.3E+01	6.0E-05	1.3E+01
SLFHC	2	6.0E-05	1.3E+01	N/A	-	6.0E-05	1.3E+01	N/A	-	N/A	-	6.0E-05	1.3E+01	6.0E-05	1.3E+01	N/A	-
SLFVC	2	6.0E-05	1.3E+01	N/A	-	6.0E-05	1.3E+01	N/A	-	N/A	-	N/A	-	6.0E-05	1.3E+01	6.0E-05	1.3E+01
SLQGC	2	6.0E-05	1.3E+01	N/A	-	6.0E-05	1.3E+01	N/A	-	N/A	-	N/A	-	6.0E-05	1.3E+01	6.0E-05	1.3E+01
SLQVC	2	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	6.0E-05	1.3E+01	6.0E-05	1.3E+01
SLRGC	2	3.2E-04	1.3E+01	N/A	-	3.2E-04	1.3E+01	N/A	-	3.2E-04	1.3E+01	N/A	-	3.2E-04	1.3E+01	3.2E-04	1.3E+01
SLRVC	2	3.2E-04	1.3E+01	N/A	-	3.2E-04	1.3E+01	N/A	-	3.2E-04	1.3E+01	N/A	-	3.2E-04	1.3E+01	3.2E-04	1.3E+01
SLSMC	2	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	4.6E-06	1.3E+01	4.6E-06	1.3E+01
SL4 - Large aircraft direct crash onto storage area; fire not contained in 30 minutes (burstered munitions detonate if hit).																	
SLBGF (80' IGL)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.0E-12	1.0E+01	4.1E-10	1.0E+01
SLBGF (89' IGL)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.1E-11	1.0E+01	N/A	-
SLBHC (60' IGL)	4	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLBHC (80' IGL)	4	2.7E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	1.6E-09	1.0E+01	9.0E-12	1.0E+01	N/A	-
SLBHC (89' IGL)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.1E-11	1.0E+01	N/A	-
SLCGC (60' IGL)	4	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLCGC (80' IGL)	4	2.7E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.0E-12	-	N/A	-
SLCGC (89' IGL)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.1E-11	-	N/A	-
SLCHC (60' IGL)	4	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLCHC (80' IGL)	4	2.7E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	1.6E-09	1.0E+01	N/A	1.0E+01	N/A	-
SLCHC (89' IGL)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	1.0E+01	N/A	-
SLIGF (80' IGL)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.0E-12	1.0E+01	N/A	-
SLIHF (60' IGL)	4	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLIHF (OPEN)	4	N/A	-	1.1E-09	1.0E+01	N/A	-	N/A	-	7.6E-09	1.0E+01	N/A	-	3.5E-09	1.0E+01	N/A	-
SLIHF (WH)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.1E-08	1.0E+01
SLIVF (80' IGL)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.0E-12	1.0E+01	N/A	-

See notes at end of table.

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TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SLXVF (MH)	4	N/A	-	N/A	-	N/A	-	1.6E-09	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-
SLMVC (60' IGL)	4	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLMVC (80' IGL)	4	2.2E-10	1.0E+01	N/A	-	N/A	-	N/A	-	4.1E-11	1.0E+01	N/A	-	9.0E-12	1.0E+01	4.1E-10	1.0E+01
SLPGC (60' IGL)	4	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLPGC (80' IGL)	4	2.2E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.0E-12	1.0E+01	4.1E-10	1.0E+01
SLPGC (89' IGL)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.1E-11	1.0E+01	N/A	-
SLPHC (60' IGL)	4	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLPHC (80' IGL)	4	2.2E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	1.6E-09	1.0E+01	9.0E-12	1.0E+01	N/A	-
SLPHC (89' IGL)	4	N/A	-	N/A	-	1.3E-10	1.0E+01	N/A	-	N/A	-	N/A	-	1.1E-11	1.0E+01	N/A	-
SLPVC (60' IGL)	4	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLPVC (80' IGL)	4	2.2E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.0E-12	1.0E+01	4.1E-10	1.0E+01
SLPVC (89' IGL)	4	N/A	-	N/A	-	1.3E-10	1.0E+01	N/A	-	N/A	-	N/A	-	1.1E-11	1.0E+01	N/A	-
SLQGC (60' IGL)	4	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLQGC (80' IGL)	4	2.2E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.0E-12	1.0E+01	4.1E-10	1.0E+01
SLQGC (89' IGL)	4	N/A	-	N/A	-	1.3E-10	1.0E+01	N/A	-	N/A	-	N/A	-	1.1E-11	1.0E+01	N/A	-
SLQVC (60' IGL)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLQVC (80' IGL)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.0E-12	1.0E+01	4.1E-10	1.0E+01
SLQVC (89' IGL)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.1E-11	1.0E+01	N/A	-
SLRGC (60' IGL)	4	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLRGC (80' IGL)	4	2.2E-10	1.0E+01	N/A	-	N/A	-	N/A	-	4.1E-1[illegible]	1.0E+01	N/A	-	9.0E-12	1.0E+01	4.1E-10	1.0E+01
SLRGC (89' IGL)	4	N/A	-	N/A	-	1.3E-10	1.0E+01	N/A	-	N/A	-	N/A	-	1.1E-11	1.0E+01	N/A	-
SLRVC (60' IGL)	4	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLRVC (80' IGL)	4	2.2E-10	1.0E+01	N/A	-	N/A	-	N/A	-	4.1E-1[illegible]	1.0E+01	N/A	-	9.0E-12	1.0E+01	4.1E-10	1.0E+01
SLRVC (89' IGL)	4	N/A	-	N/A	-	1.3E-10	1.0E+01	N/A	-	N/A	-	N/A	-	1.1E-11	1.0E+01	N/A	-
SLSVF (80' IGL)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	4.1E-10	1.0E+01
SLSVF (MH)	4	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.9E-10	1.0E+01	N/A	-
SL5 - Large aircraft indirect crash onto storage area; fire not contained in 30 minutes (burstered munitions detonate if hit).																	
SLBGF (80' IGL)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	1.1E-10	1.3E+01

See notes at end of table.

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TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SLBGF (89' IGL)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	N/A	-
SLDHC (60' IGL)	5	5.7E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLDHC (80' IGL)	5	5.9E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	4.4E-10	1.3E+01	2.7E-12	1.3E+01	N/A	-
SLDHC (89' IGL)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	N/A	-
SLCGC (60' IGL)	5	5.7E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLCGC (80' IGL)	5	5.9E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	-	N/A	-
SLCGC (89' IGL)	3	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	-	N/A	-
SLCHC (60' IGL)	5	5.7E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLCHC (80' IGL)	5	5.9E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	4.4E-10	1.3E+01	N/A	1.3E+01	N/A	-
SLCHC (89' IGL)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	1.3E+01	N/A	-
SLBGF (80' IGL)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	N/A	-
SLBHF (60' IGL)	5	5.7E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLBHF (OPEN)	5	N/A	-	2.1E-09	1.0E+01	N/A	-	N/A	-	7.9E-09	1.0E+01	N/A	-	2.7E-12	1.0E+01	N/A	-
SLBHF (WH)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.4E-08	1.1E+01
SLBVF (80' IGL)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	N/A	-
SLBVF (WH)	5	N/A	-	N/A	-	N/A	-	3.8E-09	1.1E+01	N/A	-	N/A	-	N/A	-	N/A	-
SLMVC (60' IGL)	5	5.7E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLMVC (80' IGL)	5	5.9E-11	1.3E+01	N/A	-	N/A	-	N/A	-	1.1E-11	1.3E+01	N/A	-	2.7E-12	1.3E+01	1.1E-10	1.3E+01
SLPGC (60' IGL)	5	5.7E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLPGC (80' IGL)	5	5.9E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	1.1E-10	1.3E+01
SLPGC (89' IGL)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	N/A	-
SLPHC (60' IGL)	5	5.7E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLPHC (80' IGL)	5	5.9E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	4.4E-10	1.3E+01	2.7E-12	1.3E+01	N/A	-
SLPHC (89' IGL)	5	N/A	-	N/A	-	3.4E-11	1.3E+01	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	N/A	-
SLPVC (60' IGL)	5	5.7E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLPVC (80' IGL)	5	5.9E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	1.1E-10	1.3E+01
SLPVC (89' IGL)	5	N/A	-	N/A	-	3.4E-11	1.3E+01	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	N/A	-
SLQGC (60' IGL)	5	5.7E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-

See notes at end of table.

TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	[illegible] FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SLBGC (80' IGL)	5	5.9E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	1.1E-10	1.3E+01
SLBGC (89' IGL)	5	N/A	-	N/A	-	3.4E-11	1.3E+01	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	N/A	-
SLDVC (60' IGL)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLDVC (80' IGL)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	1.1E-10	1.3E+01
SLDVC (89' IGL)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	N/A	-
SLRGC (60' IGL)	5	5.7E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLRGC (80' IGL)	5	5.9E-11	1.3E+01	N/A	-	N/A	-	N/A	-	1.1E-11	1.3E+01	N/A	-	2.7E-12	1.3E+01	1.1E-10	1.3E+01
SLRGC (89' IGL)	5	N/A	-	N/A	-	3.4E-11	1.3E+01	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	N/A	-
SLRVC (60' IGL)	5	5.7E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLRVC (80' IGL)	5	5.9E-11	1.3E+01	N/A	-	N/A	-	N/A	-	1.1E-11	1.3E+01	N/A	-	2.7E-12	1.3E+01	1.1E-10	1.3E+01
SLRVC (89' IGL)	5	N/A	-	N/A	-	3.4E-11	1.3E+01	N/A	-	N/A	-	N/A	-	2.7E-12	1.3E+01	N/A	-
SLSVF (80' IGL)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.1E-10	1.3E+01
SLSVF (WH)	5	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	6.0E-10	1.1E+01	N/A	-
SL6 - Tornado generated missiles strike the storage magazine, warehouse, or open storage area; munitions breached (no detonation).																	
SLBGC	6	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.5E-15	9.4E+01	1.2E-15	9.4E+01
SLDHC	6	4.8E-12	9.4E+01	N/A	-	N/A	-	N/A	-	N/A	-	3.2E-13	9.4E+01	5.8E-15	9.4E+01	N/A	-
SLCGC	6	4.8E-12	9.4E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	5.8E-15	9.4E+01	N/A	-
SLCHC	6	4.8E-12	9.4E+01	N/A	-	N/A	-	N/A	-	N/A	-	3.2E-13	9.4E+01	N/A	-	N/A	-
SLHGC (80' IGL)	6	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.4E-15	9.4E+01	N/A	-
SLHHC (60' IGL)	6	1.2E-12	9.4E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLHHS (OPEN)	6	N/A	-	4.4E-11	9.4E+01	N/A	-	N/A	-	9.9E-10	9.4E+01	N/A	-	1.2E-12	9.4E+01	N/A	-
SLHHC (WH)	6	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	4.9E-13	9.4E+01
SLHVC (80' ISL)	6	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.4E-15	9.4E+01	N/A	-
SLHVC (WH)	6	N/A	-	N/A	-	N/A	-	3.3E-10	9.4E+01	N/A	-	N/A	-	N/A	-	N/A	-
SLMVC	6	4.8E-12	9.4E+01	N/A	-	N/A	-	N/A	-	8.3E-12	9.4E+01	N/A	-	1.3E-14	9.4E+01	5.8E-15	9.4E+01
SLPGC	6	4.8E-12	9.4E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	5.8E-15	9.4E+01	5.8E-15	9.4E+01
SLPHC	6	4.8E-12	9.4E+01	N/A	-	4.8E-12	9.4E+01	N/A	-	N/A	-	3.2E-13	9.4E+01	5.8E-15	9.4E+01	N/A	-
SLPVC	6	4.8E-12	9.4E+01	N/A	-	4.8E-12	9.4E+01	N/A	-	N/A	-	N/A	-	5.8E-15	9.4E+01	5.8E-15	9.4E+01

See notes at end of table.

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TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SLQGC	6	4.8E-12	9.4E+01	N/A	-	4.8E-12	9.4E+01	N/A	-	N/A	-	N/A	-	5.0E-15	9.4E+01	5.0E-15	9.4E+01
SLQVC	6	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	5.0E-15	9.4E+01	5.0E-15	9.4E+01
SLRGC	6	4.8E-12	9.4E+01	N/A	-	4.8E-12	9.4E+01	N/A	-	1.9E-11	9.4E+01	N/A	-	4.8E-14	9.4E+01	5.0E-15	9.4E+01
SLRVC	6	4.8E-12	9.4E+01	N/A	-	4.8E-12	9.4E+01	N/A	-	1.9E-11	9.4E+01	N/A	-	4.8E-14	9.4E+01	5.0E-15	9.4E+01
SLSVC (80' IGL)	6	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.5E-15	9.4E+01
SLSVC (WH)	6	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.2E-13	9.4E+01	N/A	-
SL7 - Severe earthquake breaches the munitions in storage igloo; no detonations.																	
SLBGC	7	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.6E-06	1.3E+01	7.0E-08	1.3E+01
SLDHC	7	3.0E-08	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	3.0E-08	1.3E+01	7.0E-07	1.3E+01	N/A	-
SLCGC	7	7.0E-09	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.6E-07	1.3E+01	N/A	-
SLCHC	7	7.0E-09	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	7.0E-09	1.3E+01	N/A	-	N/A	-
SLKGC (80' IGL)	7	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.1E-05	1.3E+01	N/A	-
SLKHC (60' IGL)	7	4.6E-07	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLKHS (OPEN)	7	N/A	-	0.0E+00	-	N/A	-	N/A	-	0.0E+00	-	N/A	-	0.0E+00	-	N/A	-
SLKHC (WH)	7	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLKVC (80' IGL)	7	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.1E-05	1.3E+01	N/A	-
SLKVC (WH)	7	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLMVC	7	1.8E-08	1.3E+01	N/A	-	N/A	-	N/A	-	1.8E-08	1.3E+01	N/A	-	4.1E-07	1.3E+01	1.8E-08	1.3E+01
SLPGC	7	0.0E+00	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLPHC	7	0.0E+00	-	N/A	-	0.0E+00	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-	N/A	-
SLPVC	7	0.0E+00	-	N/A	-	0.0E+00	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLQGC	7	0.0E+00	-	N/A	-	0.0E+00	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLQVC	7	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLRGC	7	9.7E-08	1.3E+01	N/A	-	9.7E-08	1.3E+01	N/A	-	9.7E-08	1.3E+01	N/A	-	2.1E-06	1.3E+01	9.7E-08	1.3E+01
SLRVC	7	9.7E-08	1.3E+01	N/A	-	9.7E-08	1.3E+01	N/A	-	9.7E-08	1.3E+01	N/A	-	2.1E-06	1.3E+01	9.7E-08	1.3E+01
SLSVC (80' IGL)	7	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLSVC (WH)	7	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SL8 - Meteorite strikes the storage area; fire occurs; munitions breached (if burstered detonation occurs)																	

See notes at end of table.

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TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SLBGF	8	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	6.7E-12	2.6E+01	6.7E-12	2.6E+01
SLBHC	8	6.7E-12	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	6.7E-12	2.6E+01	6.7E-12	2.6E+01	N/A	-
SLCGC	8	6.7E-12	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	6.7E-12	2.6E+01	N/A	-
SLCHC	8	6.7E-12	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	6.7E-12	2.6E+01	N/A	-	N/A	-
SLKGF (IGL)	8	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	6.7E-12	2.6E+01	N/A	-
SLKHF (IGL)	8	6.7E-12	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLKHF (OPEN)	8	N/A	-	1.2E-11	1.7E+01	N/A	-	N/A	-	1.2E-11	1.7E+01	N/A	-	1.2E-11	1.7E+01	N/A	-
SLKHF (WH)	8	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.6E-10	2.6E+01
SLKVF (IGL)	8	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	6.7E-12	2.6E+01	N/A	-
SLKVF (WH)	8	N/A	-	N/A	-	N/A	-	1.0E-09	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-
SLMVC	8	6.7E-12	2.6E+01	N/A	-	N/A	-	N/A	-	6.7E-12	2.6E+01	N/A	-	6.7E-12	2.6E+01	6.7E-12	2.6E+01
SLPGC	8	6.7E-12	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	6.7E-12	2.6E+01	6.7E-12	2.6E+01
SLFHC	8	6.7E-12	2.6E+01	N/A	-	6.7E-12	2.6E+01	N/A	-	N/A	-	6.7E-12	2.6E+01	6.7E-12	2.6E+01	N/A	-
SLFVC	8	6.7E-12	2.6E+01	N/A	-	6.7E-12	2.6E+01	N/A	-	N/A	-	N/A	-	6.7E-12	2.6E+01	6.7E-12	2.6E+01
SLDGC	8	6.7E-12	2.6E+01	N/A	-	6.7E-12	2.6E+01	N/A	-	N/A	-	N/A	-	6.7E-12	2.6E+01	6.7E-12	2.6E+01
SLQVC	8	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	6.7E-12	2.6E+01	6.7E-12	2.6E+01
SLRGC	8	6.7E-12	2.6E+01	N/A	-	6.7E-12	2.6E+01	N/A	-	6.7E-12	2.6E+01	N/A	-	6.7E-12	2.6E+01	6.7E-12	2.6E+01
SLRVC	8	6.7E-12	2.6E+01	N/A	-	6.7E-12	2.6E+01	N/A	-	6.7E-12	2.6E+01	N/A	-	6.7E-12	2.6E+01	6.7E-12	2.6E+01
SLSVF (IGL)	8	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	6.7E-12	2.6E+01
SLSVF (WH)	8	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.7E-09	2.6E+01	N/A	-
SL9 - Munition dropped during leaker isolation activities.																	
SLBGC	9	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	6.6E-07	1.3E+01	6.6E-07	1.3E+01
SLBHC	9	4.5E-07	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	4.5E-07	1.3E+01	4.5E-07	1.3E+01	N/A	-
SLCGC	9	9.8E-08	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.8E-08	1.3E+01	N/A	-
SLCHC	9	9.8E-08	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	9.8E-08	1.3E+01	N/A	-	N/A	-
SLKGC	9	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.9E-07	1.3E+01	N/A	-
SLKHC	9	1.9E-07	1.3E+01	1.9E-07	1.3E+01	N/A	-	N/A	-	1.9E-07	1.3E+01	N/A	-	1.9E-07	1.3E+01	1.9E-07	1.3E+01
SLKVC	9	N/A	-	N/A	-	N/A	-	1.9E-07	1.3E+01	N/A	-	N/A	-	1.9E-07	1.3E+01	N/A	-

See notes at end of table.

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TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)
SLMVC	9	3.6E-07	1.3E+01	N/A	-	N/A	-	N/A	-	3.6E-07	1.3E+01	N/A	-	3.6E-07	1.3E+01	3.6E-07	1.3E+01
SLPGC	9	0.0E+00	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLPHC	9	0.0E+00	-	N/A	-	0.0E+00	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-	N/A	-
SLPVC	9	0.0E+00	-	N/A	-	0.0E+00	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLOGC	9	0.0E+00	-	N/A	-	0.0E+00	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLOVC	9	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLRGC	9	1.5E-06	1.3E+01	N/A	-	1.5E-06	1.3E+01	N/A	-	1.5E-06	1.3E+01	N/A	-	1.5E-06	1.3E+01	1.5E-06	1.3E+01
SLRVC	9	1.5E-06	1.3E+01	N/A	-	1.5E-06	1.3E+01	N/A	-	1.5E-06	1.3E+01	N/A	-	1.5E-06	1.3E+01	1.5E-06	1.3E+01
SLSVC	9	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.6E-06	1.3E+01	3.6E-06	1.3E+01
SL15 - Small aircraft direct crash onto warehouse or open storage yard; fire not contained in 30 minutes.																	
SLKGF (IGL)	15	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-
SLKHF (IGL)	15	0.0E+00	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLKHF (OPEN)	15	N/A	-	1.6E-95	1.0E+01	N/A	-	N/A	-	5.6E-07	1.0E+01	N/A	-	1.0E-07	1.0E+01	N/A	-
SLKHF (WH)	15	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	8.9E-09	1.0E+01
SLKVF (IGL)	15	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-
SLKVF (WH)	15	N/A	-	N/A	-	N/A	-	8.1E-09	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-
SLSVF (IGL)	15	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLSVF (WH)	15	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.6E-08	1.0E+01	N/A	-
SL16 - Large aircraft direct crash; no fire. (burstered munitions detonate)																	
SLRGC (80' IGL)	16	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.2E-11	1.0E+01	5.0E-10	1.0E+01
SLBGC (89' IGL)	16	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.3E-11	1.0E+01	N/A	-
SLDHC (60' IGL)	16	2.0E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLDHC (80' IGL)	16	2.6E-10	1.0E+0.	N/A	-	N/A	-	N/A	-	N/A	-	2.0E-09	1.0E+01	1.2E-11	1.0E+01	N/A	-
SLDHC (89' IGL)	16	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.3E-11	1.0E+01	N/A	-
SLCGC (60' IGL)	16	2.0E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLCGC (80' IGL)	16	2.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.2E-11	-	N/A	-
SLCGC (89' IGL)	16	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.3E-11	-	N/A	-
SLCHC (60' IGL)	16	2.0F-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-

See notes at end of table.

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TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)
SLCMC (80' IGL)	16	2.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	2.0E-09	1.0E+01	N/A	1.0E+01	N/A	-
SLCMC (89' IGL)	16	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	1.0E+01	N/A	-
SLEGC (80' IGL)	16	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.2E-11	1.0E+01	N/A	-
SLHMC (60' IGL)	16	2.0E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLKHS (OPEN)	16	N/A	-	1.3E-09	1.0E+01	N/A	-	N/A	-	9.4E-09	1.0E+01	N/A	-	4.3E-09	1.0E+01	N/A	-
SLKHS (MH)	16	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.8E-08	1.0E+01
SLKVC (80' IGL)	16	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.2E-11	1.0E+01	N/A	-
SLKVS (MH)	16	N/A	-	N/A	-	N/A	-	2.0E-09	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-
SLMVC (60' IGL)	16	2.0E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLMVC (80' IGL)	16	2.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	5.0E-11	1.0E+01	N/A	-	1.2E-11	1.0E+01	5.0E-10	1.0E+01
SLPGC (60' IGL)	16	2.0E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLPGC (80' IGL)	16	2.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.2E-11	1.0E+01	5.0E-10	1.0E+01
SLPGC (89' IGL)	16	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.3E-11	1.0E+01	N/A	-
SLPMC (60' IGL)	16	2.0E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLPMC (80' IGL)	16	2.6E-10	1.5E+01	N/A	-	N/A	-	N/A	-	N/A	-	2.0E-09	1.0E+01	1.2E-11	1.0E+01	N/A	-
SLPMC (89' IGL)	16	N/A	-	N/A	-	N/A	1.0E+01	N/A	-	N/A	-	N/A	-	1.3E-11	1.0E+01	N/A	-
SLPVC (60' IGL)	16	2.0E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLPVC (80' IGL)	16	2.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.2E-11	1.0E+01	5.0E-10	1.0E+01
SLPVC (89' IGL)	16	N/A	-	N/A	-	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	1.3E-11	1.0E+01	N/A	-
SLQGC (60' IGL)	16	2.0E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLQGC (80' IGL)	16	2.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.2E-11	1.0E+01	5.0E-10	1.0E+01
SLQGC (89' IGL)	16	N/A	-	N/A	-	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	1.3E-11	1.0E+01	N/A	-
SLQVC (60' IGL)	16	2.0E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLQVC (80' IGL)	16	2.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.2E-11	1.0E+01	5.0E-10	1.0E+01
SLQVC (89' IGL)	16	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.3E-11	1.0E+01	N/A	-
SLRGC (60' IGL)	16	2.0E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLRGC (80' IGL)	16	2.5E-10	1.0E+01	N/A	-	N/A	-	N/A	-	5.0E-11	1.0E+01	N/A	-	1.2E-11	1.0E+01	5.0E-10	1.0E+01
SLRGC (89' IGL)	16	N/A	-	N/A	-	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	1.3E-11	1.0E+01	N/A	-

See notes at end of table.

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TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	AMAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)
SLRVC (60' IGL)	16	2.0E-10	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLRVC (80' IGL)	16	2.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	5.0E-11	1.0E+01	N/A	-	1.2E-11	1.0E+01	5.0E-10	1.0E+01
SLRVC (89' IGL)	16	N/A	-	N/A	-	1.6E-10	1.0E+01	N/A	-	N/A	-	N/A	-	1.3E-11	1.0E+01	N/A	-
SLSVC (80' IGL)	16	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	5.0E-10	1.0E+01
SLSVS (WH)	16	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	4.0E-10	1.0E+01	N/A	-
SL17 - large aircraft direct crash; fire contained within 30 minutes. (Applies to non-burstered munitions only)																	
SLKHF (OPEN)	17	N/A	-	3.7E-13	1.0E+01	N/A	-	N/A	-	2.6E-12	1.0E+01	N/A	-	1.2E-12	1.0E+01	N/A	-
SLKHF (WH)	17	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.0E-12	1.0E+01
SLKVF (WH)	17	N/A	-	N/A	-	N/A	-	5.6E-13	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-
SLSVF (WH)	17	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.3E-13	1.0E+01	N/A	-
SL18 - Small aircraft direct crash onto warehouse or open storage yard; no fire.																	
SLKHS (OPEN)	18	N/A	-	2.0E-05	1.0E+01	N/A	-	N/A	-	6.9E-07	1.0E+01	N/A	-	1.7E-07	1.0E+01	N/A	-
SLKHS (WH)	18	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.1E-08	1.0E+01
SLKVS (WH)	18	N/A	-	N/A	-	N/A	-	1.0E-08	1.0E+01	N/A	-	N/A	-	N/A	-	N/A	-
SLSVS (WH)	18	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.9E-08	1.0E+01	N/A	-
SL19 - Small aircraft direct crash onto warehouse or open storage yard; fire contained in 30 minutes.																	
SLKHF (OPEN)	19	N/A	-	3.0E-07	1.3E+01	N/A	-	N/A	-	1.1E-08	1.3E+01	N/A	-	2.7E-09	1.3E+01	N/A	-
SLKHF (WH)	19	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.0E-10	1.3E+01
SLKVF (WH)	19	N/A	-	N/A	-	N/A	-	1.5E-10	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-
SLSVF (WH)	19	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.0E-10	1.3E+01	N/A	-
SL20 - Large aircraft indirect crash onto storage area; no fire.																	
SLBGC (80' IGL)	20	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.3E-12	1.3E+01	1.4E-10	1.3E+01
SLBGC (89' IGL)	20	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.4E-12	1.3E+01	N/A	-
SLDHC (60' IGL)	20	7.0E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLDHC (80' IGL)	26	7.3E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	5.0E-10	1.3E+01	3.3E-12	1.3E+01	N/A	-
SLDHC (89' IGL)	20	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.0E-12	1.3E+01	N/A	-
SLCGC (60' IGL)	20	7.0E-12	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLCGC (80' IGL)	20	7.3E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.3E-12	-	N/A	-

See notes at end of table.

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TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER) PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)
SLCGC (89' IGL)	20	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.4E-12	-	N/A	-
SLCHC (60' IGL)	20	7.0E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLCHC (80' IGL)	20	7.3E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	5.4E-10	1.3E+01	N/A	1.3E+01	N/A	-
SLCHC (89' IGL)	20	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	1.3E+01	N/A	-
SLEGC (80' IGL)	20	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.3E-12	1.3E+01	N/A	-
SLEHC (60' IGL)	20	7.0E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLEMS (OPEN)	20	N/A	-	2.6E-09	1.0E+01	N/A	-	N/A	-	9.7E-09	1.0E+01	N/A	-	3.5E-09	1.0E+01	N/A	-
SLEHC (NH)	20	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.7E-08	1.1E+01
[illegible] (80' IGL)	20	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.3E-12	1.3E+01	N/A	-
SLEVC (NH)	20	N/A	-	N/A	-	N/A	-	4.7E-09	1.1E+01	N/A	-	N/A	-	N/A	-	N/A	-
SLMVC (60' IGL)	20	7.0E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLMVC (80' IGL)	20	7.3E-11	1.3E+01	N/A	-	N/A	-	N/A	-	1.4E-11	1.3E+01	N/A	-	3.3E-12	1.3E+01	1.4E-10	1.3E+01
SLPGC (60' IGL)	20	7.0E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLPGC (80' IGL)	20	7.3E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.3E-12	1.3E+01	1.4E-10	1.3E+01
SLPGC (89' IGL)	20	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.4E-12	1.3E+01	N/A	-
SLPHC (60' IGL)	20	7.0E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLPHC (80' IGL)	20	7.3E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	5.4E-10	1.3E+01	3.3E-12	1.3E+01	N/A	-
SLPHC (89' IGL)	20	N/A	-	N/A	-	4.2E-11	1.3E+01	N/A	-	N/A	-	N/A	-	3.4E-12	1.3E+01	N/A	-
SLPVC (60' IGL)	20	7.0E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLPVC (80' IGL)	20	7.3E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.3E-12	1.3E+01	1.4E-10	1.3E+01
SLPVC (89' IGL)	20	N/A	-	N/A	-	4.2E-11	1.3E+01	N/A	-	N/A	-	N/A	-	3.4E-12	1.3E+01	N/A	-
SLOGC (60' IGL)	20	7.0E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLOGC (80' IGL)	20	7.3E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.3E-12	1.3E+01	1.4E-10	1.3E+01
SLOGC (89' IGL)	20	N/A	-	N/A	-	4.2E-11	1.3E+01	N/A	-	N/A	-	N/A	-	3.4E-12	1.3E+01	N/A	-
SLOVC (60' IGL)	20	7.0E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLOVC (80' IGL)	20	7.3E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.3E-12	1.3E+01	1.4E-10	1.3E+01
SLOVC (89' IGL)	20	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.4E-12	1.3E+01	N/A	-
SLRGC (60' IGL)	20	7.0E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-

See notes at end of table.

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TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)
SLRGC (80' IGL)	20	7.3E-11	1.3E+01	N/A	-	N/A	-	N/A	-	1.4E-11	1.3E+01	N/A	-	3.3E-12	1.3E+01	1.4E-10	1.3E+01
SLRGC (89' IGL)	20	N/A	-	N/A	-	4.2E-11	1.3E+01	N/A	-	N/A	-	N/A	-	3.4E-12	1.3E+01	N/A	-
SLRVC (60' IGL)	20	7.0E-11	1.3E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLRVC (80' IGL)	20	7.3E-11	1.3E+01	N/A	-	N/A	-	N/A	-	1.4E-11	1.3E+01	N/A	-	3.3E-12	1.3E+01	1.4E-10	1.3E+01
SLRVC (89' IGL)	20	N/A	-	N/A	-	4.2E-11	1.3E+01	N/A	-	N/A	-	N/A	-	3.4E-12	1.3E+01	N/A	-
SLSVC (80' IGL)	20	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.4E-10	1.3E+01
SLSVC (MH)	20	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	7.4E-10	1.1E+01	N/A	-
SL21 - large aircraft indirect crash onto storage area; fire contained in 30 minutes																	
SLDGF (80' IGL)	21	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.2E-16	-	0.0E+00	-
SLDGF (89' IGL)	21	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.3E-16	-	N/A	-
SLFGF (80' IGL)	21	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.2E-16	-	N/A	-
SLRHF (60' IGL)	21	1.9E-10	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLRHF (OPEN)	21	N/A	-	7.2E-13	1.0E+01	N/A	-	N/A	-	2.7E-12	1.0E+01	N/A	-	9.7E-13	1.0E+01	N/A	-
SLRHF (MH)	21	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	4.8E-12	1.1E+01
SLRVF (80' IGL)	21	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	9.2E-16	1.3E+01	N/A	-
SLRVF (MH)	21	N/A	-	N/A	-	N/A	-	1.3E-12	1.1E+01	N/A	-	N/A	-	N/A	-	N/A	-
SLSVF (80' IGL)	21	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-
SLSVF (MH)	21	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	2.1E-13	1.1E+01	N/A	-
SL22 - Severe earthquake leads to munition detonation																	
SLRGC	22	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLDMC	22	1.2E-08	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	1.2E-08	2.6E+01	2.7E-07	2.6E+01	N/A	-
SLCGC	22	6.2E-07	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.4E-07	2.6E+01	N/A	-
SLCMC	22	6.2E-07	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	6.2E-07	2.6E+01	N/A	-	N/A	-
SLRGS (IGL)	22	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-
SLRHS (IGL)	22	0.0E+00	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLRHS (OPEN)	22	N/A	-	0.0E+00	-	N/A	-	N/A	-	0.0E+00	-	N/A	-	0.0E+00	-	N/A	-
SLRHS (MH)	22	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-
SLRVS (IGL)	22	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-

See notes at end of table.

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TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEANER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)
SLKVS (WH)	22	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-	N/A	-	N/A	-	N/A	-
SLNVC	22	7.0E-09	2.6E+01	N/A	-	N/A	-	N/A	-	7.0E-09	2.6E+01	N/A	-	1.6E-07	2.6E+01	7.9E-09	2.6E+01
SLFGC	22	4.7E-09	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	1.0E-07	2.6E+01	5.3E-09	2.6E+01
SLFHC	22	4.7E-09	2.6E+01	N/A	-	4.7E-09	2.6E+01	N/A	-	N/A	-	4.7E-09	2.6E+01	1.0E-07	2.6E+01	N/A	-
SLPVC	22	4.7E-09	2.6E+01	N/A	-	4.7E-09	2.6E+01	N/A	-	N/A	-	N/A	-	1.0E-07	2.6E+01	4.7E-09	2.6E+01
SLOGC	22	3.4E-09	2.6E+01	N/A	-	3.4E-09	2.6E+01	N/A	-	N/A	-	N/A	-	7.6E-08	2.6E+01	3.4E-09	2.6E+01
SLOVC	22	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	7.6E-08	2.6E+01	3.4E-09	2.6E+01
SLRGC	22	3.9E-09	2.6E+01	N/A	-	3.9E-09	2.6E+01	N/A	-	3.9E-09	2.6E+01	N/A	-	8.9E-08	2.6E+01	3.9E-09	2.6E+01
SLRYC	22	3.9E-09	2.6E+01	N/A	-	3.9E-09	2.6E+01	N/A	-	3.9E-09	2.6E+01	N/A	-	8.9E-08	2.6E+01	3.9E-09	2.6E+01
SLSVF (IGL)	22	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-
SLSVF (WH)	22	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-
SL23 - Tornado generated missiles strike the storage igloo and cause munition detonation.																	
SLDGS	23	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLBHC	23	3.0E-13	9.9E+01	N/A	-	N/A	-	N/A	-	N/A	-	2.2E-14	9.9E+01	3.2E-16	9.9E+01	N/A	-
SLCGC	23	3.0E-13	9.9E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.2E-16	9.9E+01	N/A	-
SLCHC	23	3.0E-13	9.9E+01	N/A	-	N/A	-	N/A	-	N/A	-	2.2E-14	9.9E+01	N/A	-	N/A	-
SLKGS (IGL)	23	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-
SLKHS (IGL)	23	0.0E+00	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-
SLKHS (OPEN)	23	N/A	-	0.0E+00	-	N/A	-	N/A	-	0.0E+00	-	N/A	-	0.0E+00	-	N/A	-
SLKHS (WH)	23	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-
SLKVS (IGL)	23	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-
SLKVS (WH)	23	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-	N/A	-	N/A	-	N/A	-
SLNVC	23	3.4E-13	9.9E+01	N/A	-	N/A	-	N/A	-	4.6E-13	9.9E+01	N/A	-	7.0E-16	9.9E+01	6.0E-16	9.9E+01
SLFGC	23	3.4E-13	9.9E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.2E-16	9.9E+01	4.9E-16	9.9E+01
SLFHC	23	3.4E-13	9.9E+01	N/A	-	3.4E-13	9.9E+01	N/A	-	N/A	-	2.2E-14	9.9E+01	3.2E-16	9.9E+01	N/A	-
SLFVC	23	3.4E-13	9.9E+01	N/A	-	3.4E-13	9.9E+01	N/A	-	N/A	-	N/A	-	3.2E-16	9.9E+01	4.0E-16	9.9E+01
SLOGC	23	3.4E-13	9.9E+01	N/A	-	3.4E-13	9.9E+01	N/A	-	N/A	-	N/A	-	3.2E-16	9.9E+01	4.0E-16	9.9E+01
SLOVC	23	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.2E-16	9.9E+01	4.0E-16	9.9E+01

See notes at end of table.

TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
(S)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)
SLRGC	23	3.4[illegible]	9.9E+01	N/A	-	3.4E-13	9.9E+01	N/A	-	1.1E-12	9.9E+01	N/A	-	2.6E-15	9.9E+01	4.0E-16	9.9E+01
SLRVC	23	3.[illegible]3	9.9E+01	N/A	-	3.4E-13	9.9E+01	N/A	-	1.1E-12	9.9E+01	N/A	-	2.6E-15	9.9E+01	4.0E-16	9.9E+01
SLSVS (IGL)	23	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-
SLSVS (UNI)	23	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-
SL24 - Lightning strikes ton containers stored outdoors.																	
SLIHS (OPEN)	24	N/A	-	1.4E-13	1.0E+01	N/A	-	N/A	-	3.1E-10	1.5E+01	N/A	-	1.4E-10	1.0E+01	N/A	-
SL25 - Munitions dropped during leaker isolation; munition detonates.																	
SLBGC	25	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLBHC	25	1.7E-07	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	1.7E-07	2.6E+01	1.7E-07	2.6E+01	N/A	-
SLCGC	25	8.9E-08	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	8.9E-08	2.6E+01	N/A	-
SLCHC	25	8.9E-08	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	8.9E-08	2.6E+01	N/A	-	N/A	-
SLIGC	25	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-
SLIHC	25	0.0E+00	-	0.0E+00	-	N/A	-	N/A	-	N/A	-	N/A	-	0.0E+00	-	0.0E+00	-
SLKVC	25	N/A	-	N/A	-	N/A	-	0.0E+00	-	N/A	-	N/A	-	0.0E+00	-	N/A	-
SLMVC	25	1.3E-07	2.6E+01	N/A	-	N/A	-	N/A	-	1.3E-07	2.6E+01	N/A	-	1.3E-07	2.6E+01	1.3E-07	2.6E+01
SLPGC	25	3.2E-08	2.6E+01	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.2E-08	2.6E+01	3.2E-08	2.6E+01
SLPHC	25	3.2E-08	2.6E+01	N/A	-	3.2E-08	2.6E+01	N/A	-	N/A	-	3.2E-08	2.6E+01	3.2E-08	2.6E+01	N/A	-
SLPVC	25	3.2E-08	2.6E+01	N/A	-	3.2E-08	2.6E+01	N/A	-	N/A	-	N/A	-	3.2E-08	2.6E+01	3.2E-08	2.6E+01
SLQGC	25	3.2E-08	2.6E+01	N/A	-	3.2E-08	2.6E+01	N/A	-	N/A	-	N/A	-	3.2E-08	2.6E+01	3.2E-08	2.6E+01
SLQVC	25	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	N/A	-	3.2E-08	2.6E+01	3.2E-08	2.6E+01
SLRGC	25	5.7E-08	2.6E+01	N/A	-	5.7E-08	2.6E+01	N/A	-	5.7E-08	2.6E+01	N/A	-	5.7E-08	2.6E+01	5.7E-08	2.6E+01
SLRVC	25	5.7E-08	2.6E+01	N/A	-	5.7E-08	2.6E+01	N/A	-	5.7E-08	2.6E+01	N/A	-	5.7E-08	2.6E+01	5.7E-08	2.6E+01
SLSVC	25	N/A	-	N/A	-	N/A	-	N/A	-	N/A		N/A	-	0.0E+00	-	0.0E+00	-

NOTES:

See notes at end of table.

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TABLE 5-19 (Continued)

STORAGE ACCIDENTS - CONTINUED STORAGE OPTION - PER IGLOO (OR LEAKER)
PER YEAR STORAGE FOR MUNITIONS AT EXISTING SITES

Accident Frequencies

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)

1. Frequency units for scenario 1 are events per munition year.

2. Frequency units for scenarios 2, 9, and 25 are events per leaker.

3. Frequency units for scenarios 4, 5, 8, 15 through 21, and 23 are events per storage unit-year (igloo or warehouse). For ton containers stored outdoors, frequency units for scenarios 8 and 24 are events per cluster-year of ton containers (15 TC/cluster).

4. Agent release for SLKHS 1 (open) assumes outdoor spill onto a porous surface.

5. Frequency units for scenarios 7 and 22 are events per year.

TABLE 5-20
FREQUENCY OF EARTHQUAKE STORAGE ACCIDENTS
(STORAGE AT EXISTING SITES)

STORAGE EARTHQUAKE - WAREHOUSES

CONTINUED STORAGE OPTION - EARTHQUAKE-INDUCED ACCIDENTS IN THE WAREHOUSES
(PER YEAR)

ACCIDENT FREQUENCIES

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SLYVF	261	N/A	N/A	N/A	N/A	N/A	N/A	1.1E-06	1.0E+01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SLYVC	262	N/A	N/A	N/A	N/A	N/A	N/A	9.5E-07	2.0E+01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SLYVF	263	N/A	N/A	N/A	N/A	N/A	N/A	1.1E-09	2.9E+01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SLYVF	264	N/A	N/A	N/A	N/A	N/A	N/A	3.3E-04	5.5E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SLYVC	265	N/A	N/A	N/A	N/A	N/A	N/A	1.4E-04	8.6E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SLSVF	271	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.7E-04	8.6E+00	N/A	N/A
SLSVF	272	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.3E-06	7.1E+00	N/A	N/A
SLSVF	273	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.1E-05	9.3E+00	N/A	N/A
SLSVF	274	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.9E-06	1.1E+01	N/A	N/A
SLSVF	275	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.0E-07	3.4E+01	N/A	N/A
SLSVF	276	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.8E-08	2.8E+01	N/A	N/A
SLYHF	281	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.8E-07	1.2E+01
SLYHF	282	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.3E-05	8.8E+00
SLYHF	283	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.9E-07	1.9E+01
SLYHC	284	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.1E-10	3.1E+01
SLYHF	285	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.1E-10	3.1E+01
SLYHF	286	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	NEGL	
SLYHF	287	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.5E-10	5.8E+01
SLYHC	288	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	NEGL	
SLYHF	289	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	NEGL	
SLYHF	2810	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.4E-05	1.2E+01
SLYHF	2811	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.9E-05	7.5E+00
SLYHF	2812	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.3E-07	9.2E+00
SLYHF	2813	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.6E-08	2.3E+01
SLYHF	2814	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.7E-08	2.7E+01

TABLE 5-20 (Continued)

STORAGE EARTHQUAKE - WAREHOUSES

CONTINUED STORAGE OPTION - EARTHQUAKE-INDUCED ACCIDENTS IN THE WAREHOUSES
(PER YEAR)

ACCIDENT FREQUENCIES

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANEF FACTOR	TEAD FREQ	RANGE FACTOR	USGA FREQ	RANGE FACIDR
SLPHF	2815	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.8E-10	2.7E+01
SLPHF	2816	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5.6E-05	5.2E+00
SLPHF	2817	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.1E-05	9.8E+00

TABLE 5-21

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FREQUENCY OF ACCIDENTS RELATED TO SURVEILLANCE AND MAINTENANCE

CONTINUED STORAGE OPTION - HANDLING ACCIDENTS RELATED TO SURVEILLANCE AND MAINTENANCE
(PER PALLET- OR CONTAINER-YEAR)

ACCIDENT FREQUENCIES

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
Drop of pallet or container in storage area or maintenance facility; munition punctured																	
SHBGC	1	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	4.6E-08	1.3E+01	4.6E-08	1.3E+01
SHBHC	1	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--	N/A	--
SHCGC	1	1.4E-09	1.3E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	1.4E-09	1.3E+01	N/A	--
SHCHC	1	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	N/A	--
SHTGC	1	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	4.8E-09	1.3E+01	N/A	--
SHTHC	1	4.8E-09	1.3E+01	3.2E-09	1.3E+01	N/A	--	N/A	--	3.2E-09	1.3E+01	N/A	--	3.2E-09	1.3E+01	4.8E-09	1.3E+01
SHTVC	1	N/A	--	N/A	--	N/A	--	4.8E-09	1.3E+01	N/A	--	N/A	--	4.8E-09	1.3E+01	N/A	--
SHMVC	1	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHPGC	1	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHPHC	1	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--	N/A	--
SHPVC	1	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHQGC	1	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHQVC	1	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHRGC	1	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHRVC	1	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHSVC	1	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
Forklift collision with short duration fire																	
SHBGF	2	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	3.1E-11	3.1E+01	3.1E-11	3.1E+01
SHBHF	2	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--	N/A	--
SHCGF	2	1.1E-13	3.1E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	1.1E-13	3.1E+01	N/A	--
SHCHF	2	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	N/A	--
SHTGF	2	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	4.2E-11	3.1E+01	N/A	--
SHTHF	2	4.2E-11	3.1E+01	4.2E-11	3.1E+01	N/A	--	N/A	--	4.2E-11	3.1E+01	N/A	--	4.2E-11	3.1E+01	4.2E-11	3.1E+01
SHTVF	2	N/A	--	N/A	--	N/A	--	4.2E-11	3.1E+01	N/A	--	N/A	--	4.2E-11	3.1E+01	N/A	--
SHMVF	2	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHPGF	2	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHPHF	2	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--	N/A	--

See notes at end of table.

TABLE 5-21 (Continued)

CONTINUED STORAGE OPTION - HANDLING ACCIDENTS RELATED TO SURVEILLANCE AND MAINTENANCE
(PER PALLET- OR CONTAINER-YEAR)

ACCIDENT FREQUENCIES

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SHFVF	2	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHCGF	2	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHDVF	2	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHRGF	2	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHRVF	2	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHSVF	2	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
Forklift tine puncture																	
SHRGC	3	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	9.7E-08	1.3E+01	9.7E-08	1.3E+01
SHDHC	3	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--	N/A	--
SHFGC	3	4.3E-08	1.3E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	4.3E-08	1.3E+01	N/A	--
SHCHC	3	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	N/A	--
SHRVC	3	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHFGC	3	2.4E-07	1.3E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	2.4E-07	1.3E+01	2.4E-07	1.3E+01
SHFHC	3	1.2E-06	1.3E+01	N/A	--	1.2E-06	1.3E+01	N/A	--	N/A	--	1.2E-06	1.3E+01	1.2E-06	1.3E+01	N/A	--
SHFVC	3	2.5E-07	1.3E+01	N/A	--	2.5E-07	1.3E+01	N/A	--	N/A	--	N/A	--	2.5E-07	1.3E+01	2.5E-07	1.3E+01
SHGGC	3	2.6E-07	1.3E+01	N/A	--	2.6E-07	1.3E+01	N/A	--	N/A	--	N/A	--	2.6E-07	1.3E+01	2.6E-07	1.3E+01
SHQVC	3	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	2.6E-07	1.3E+01	2.6E-07	1.3E+01
SHRGC	3	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHRVC	3	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHSVC	3	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
Forklift collision without fire																	
SHRGC	4	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	1.2E-09	1.3E+01	1.2E-09	1.3E+01
SHDHC	4	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--	N/A	--
SHCGC	4	8.7E-12	1.3E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	8.7E-12	1.3E+01	N/A	--
SHCHC	4	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	N/A	--
SHFGC	4	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	1.6E-09	1.3E+01	N/A	--
SHFHC	4	1.6E-09	1.3E+01	1.1E-09	1.3E+01	N/A	--	N/A	--	1.1E-09	1.3E+01	N/A	--	1.1E-09	1.3E+01	1.6E-09	1.3E+01
SHRVC	4	N/A	--	N/A	--	N/A	--	1.6E-09	1.3E+01	N/A	--	N/A	--	1.6E-09	1.3E+01	N/A	--

See notes at end of table.

TABLE 5-21 (Continued)

CONTINUED STORAGE OPTION - HANDLING ACCIDENTS RELATED TO SURVEILLANCE AND MAINTENANCE
(PER PALLET- OR CONTAINER-YEAR)

ACCIDENT FREQUENCIES

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SHAVC	4	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHP6C	4	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHPHC	4	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--	N/A	--
SHPVC	4	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHOSC	4	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHOVC	4	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHR6C	4	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	-	0.0E+00	--	0.0E+00	--
SHRVC	4	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHSVC	4	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
Drop of munition leads to detonation																	
SHDHC	5	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--	N/A	--
SHC6C	5	1.1E-11	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	1.1E-11	2.6E+01	N/A	--
SHCHC	5	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	N/A	--
SHMVC	3	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHF6C	5	3.7E-12	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	3.7E-12	2.6E+01	3.7E-12	2.6E+01
SHFHC	5	1.9E-11	2.6E+01	N/A	--	1.9E-11	2.6E+01	N/A	--	N/A	--	1.9E-11	2.6E+01	1.9E-11	2.6E+01	N/A	--
SHFVC	5	4.0E-12	2.6E+01	N/A	--	4.0E-12	2.6E+01	N/A	--	N/A	--	N/A	--	4.0E-12	2.6E+01	4.0E-12	2.6E+01
SHOSC	5	3.0E-12	2.6E+01	N/A	--	3.0E-12	2.6E+01	N/A	--	N/A	--	N/A	--	3.0E-12	2.6E+01	3.0E-12	2.6E+01
SHOVC	5	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	3.0E-12	2.6E+01	3.0E-12	2.6E+01
SHREC	5	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHRVC	5	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
Collision accident leads to detonation																	
SHDHC	6	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--	N/A	--
SHCEC	6	6.2E-17	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	6.2E-17	2.6E+01	N/A	--
SHCHC	6	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	N/A	--
SHMVC	6	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHF6C	6	2.1E-17	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	2.1E-17	2.6E+01	2.1E-17	2.6E+01
SHFHC	6	1.0E-16	2.6E+01	N/A	--	1.0E-16	2.6E+01	N/A	--	N/A	--	1.0E-16	2.6E+01	1.0E-16	2.6E+01	N/A	--

See notes at end of table.

TABLE 5-21 (Continued)

CONTINUED STORAGE OPTION - HANDLING ACCIDENTS RELATED TO SURVEILLANCE AND MAINTENANCE
(PER PALLET- OR CONTAINER-YEAR)

ACCIDENT FREQUENCIES

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SHPVC	6	2.2E-17	2.6E+01	N/A	--	2.2E-17	2.6E+01	N/A	--	N/A	--	N/A	--	2.2E-17	2.6E+01	2.2E-17	2.6E+01
SHQGC	6	1.8E-17	2.6E+01	N/A	--	1.8E-17	2.6E+01	N/A	--	N/A	--	N/A	--	1.8E-17	2.6E+01	1.8E-17	2.6E+01
SHQVC	6	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	1.8E-17	2.6E+01	1.8E-17	2.6E+01
SHRGC	6	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHRVC	6	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
Collision accident with prolonged fire																	
SHBGC	7	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHDHC	7	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--	N/A	--
SHCGC	7	2.5E-08	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	2.5E-08	2.6E+01	N/A	--
SHCHC	7	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	N/A	--
SHKGC	7	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--
SHKHC	7	0.0E+00	--	0.0E+00	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHLVC	7	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	0.0E+00	--	N/A	--
SHMVC	7	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHFGC	7	2.5E-08	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	2.5E-08	2.6E+01	2.5E-08	2.6E+01
SHFHC	7	1.2E-07	2.6E+01	N/A	--	1.2E-07	2.6E+01	N/A	--	N/A	--	1.2E-07	2.6E+01	1.2E-07	2.6E+01	N/A	--
SHPVC	7	2.6E-08	2.6E+01	N/A	--	2.6E-08	2.6E+01	N/A	--	N/A	--	N/A	--	2.6E-08	2.6E+01	2.6E-08	2.6E+01
SHQGC	7	2.7E-08	2.6E+01	N/A	--	2.7E-08	2.6E+01	N/A	--	N/A	--	N/A	--	2.7E-08	2.6E+01	2.7E-08	2.6E+01
SHQVC	7	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	2.7E-08	2.6E+01	2.7E-08	2.6E+01
SHNGC	7	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHRVC	7	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	0.0E+00	--	0.0E+00	--
SHSVC	7	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
Munition pallet dropped during pallet inspection																	
SHBGC	8	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	1.2E-07	1.3E+01	1.2E-07	1.3E+01
SHDHC	8	3.2E-08	1.3E+01	N/A	--	N/A	--	N/A	--	N/A	--	3.2E-08	1.3E+01	3.2E-08	1.3E+01	N/A	--
SHCGC	8	5.7E-09	1.3E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	5.7E-09	1.3E+01	N/A	--
SHCHC	8	5.7E-09	1.3E+01	N/A	--	N/A	--	N/A	--	N/A	--	5.7E-09	1.3E+01	N/A	--	N/A	--
SHMVC	8	2.4E-08	1.3E+01	N/A	--	N/A	--	N/A	--	2.4E-08	1.3E+01	N/A	--	2.4E-08	1.3E+01	2.4E-08	1.3E+01

See notes at end of table.

TABLE 5-21 (Continued)

CONTINUED STORAGE OPTION - HANDLING ACCIDENTS RELATED TO SURVEILLANCE AND MAINTENANCE
(PER PALLET- OR CONTAINER-YEAR)

ACCIDENT FREQUENCIES

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SHFGC	8	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHFHC	8	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--	N/A	--
SHFVC	8	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHOGC	8	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHOVC	8	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHRGC	8	9.5E-08	1.3E+01	N/A	--	9.5E-08	1.3E+01	N/A	--	9.5E-08	1.3E+01	N/A	--	9.5E-08	1.3E+01	9.5E-08	1.3E+01
SHRVC	8	9.5E-08	1.3E+01	N/A	--	9.5E-08	1.3E+01	N/A	--	9.5E-08	1.3E+01	N/A	--	9.5E-08	1.3E+01	9.5E-08	1.3E+01
Forklift tine puncture during pallet inspection																	
SHBGC	9	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	2.6E-07	1.3E+01	2.6E-07	1.3E+01
SHDHC	9	7.4E-07	1.3E+01	N/A	--	N/A	--	N/A	-	N/A	--	7.4E-07	1.3E+01	7.4E-07	1.3E+01	N/A	--
SHCGC	9	1.8E-07	1.3E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	1.8E-07	1.3E+01	N/A	--
SHCHC	9	1.8E-07	1.3E+01	N/A	--	N/A	--	N/A	--	N/A	--	1.8E-07	1.3E+01	N/A	--	N/A	--
SHMVC	9	1.4E-06	1.3E+01	N/A	--	N/A	--	N/A	--	1.4E-06	1.3E+01	N/A	--	1.4E-06	1.3E+01	1.4E-06	1.3E+01
SHFGC	9	1.0E-06	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	1.0E-06	1.3E+01	1.0E-06	1.3E+01
SHPHC	9	1.0E-06	--	N/A	--	1.0E-06	1.3E+01	N/A	--	N/A	--	1.0E-06	1.3E+01	1.0E-06	1.3E+01	N/A	--
SHFVC	9	1.0E-06	--	N/A	--	1.0E-06	1.3E+01	N/A	--	N/A	--	N/A	--	1.0E-06	1.3E+01	1.0E-06	1.3E+01
SHOGC	9	1.0E-06	--	N/A	--	1.0E-06	1.3E+01	N/A	--	N/A	--	N/A	--	1.0E-06	1.3E+01	1.0E-06	1.3E+01
SHOVC	9	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	1.0E-06	1.3E+01	1.0E-06	1.3E+01
SHRGC	9	5.3E-06	1.3E+01	N/A	--	5.3E-06	1.3E+01	N/A	--	5.3E-06	1.3E+01	N/A	--	5.3E-06	1.3E+01	5.3E-06	1.3E+01
SHRVC	9	5.3E-06	1.3E+01	N/A	--	5.3E-06	1.3E+01	N/A	--	5.3E-06	1.3E+01	N/A	--	5.3E-06	1.3E+01	5.3E-06	1.3E+01
Forklift collision during pallet inspection																	
SHBGC	10	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	3.4E-09	1.3E+01	3.4E-09	1.3E+01
SHBHC	10	1.6E-09	1.3E+01	N/A	--	N/A	--	N/A	--	N/A	--	1.6E-09	1.3E+01	1.6E-09	1.3E+01	N/A	--
SHCGC	10	3.9E-11	1.3E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	3.9E-11	1.3E+01	N/A	--
SHCHC	10	3.9E-11	1.3E+01	N/A	--	N/A	--	N/A	--	N/A	--	3.9E-11	1.3E+01	N/A	--	N/A	--
SHPVC	10	1.4E-09	1.3E+01	N/A	--	N/A	--	N/A	--	1.4E-09	1.3E+01	N/A	--	1.4E-09	1.3E+01	1.4E-09	1.3E+01
SHFGC	10	0.0E+00	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHFHC	10	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--	N/A	--

See notes at end of table.

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TABLE 5-21 (Continued)

CONTINUED STORAGE OPTION - HANDLING ACCIDENTS RELATED TO SURVEILLANCE AND MAINTENANCE
(PER PALLET- OR CONTAINER-YEAR)

ACCIDENT FREQUENCIES

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SHFVC	10	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHQGC	10	0.0E+00	--	N/A	--	0.0E+00	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHQVC	10	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	0.0E+00	--	0.0E+00	--
SHRGC	10	6.2E-09	1.3E+01	N/A	--	6.2E-09	1.3E+01	N/A	--	6.2E-09	1.3E+01	N/A	--	6.2E-09	1.3E+01	6.2E-09	1.3E+01
SHRVC	10	6.2E-09	1.3E+01	N/A	--	6.2E-09	1.3E+01	N/A	--	6.2E-09	1.3E+01	N/A	--	6.2E-09	1.3E+01	6.2E-09	1.3E+01
Munition pallet dropped during pallet inspection; detonation occurs																	
SHDHC	11	9.2E-11	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	9.2E-11	2.6E+01	9.2E-11	2.6E+01	N/A	--
SHCGC	11	4.4E-11	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	4.4E-11	2.6E+01	N/A	--
SHCHC	11	4.4E-11	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	4.4E-11	2.6E+01	N/A	--	N/A	--
SHMVC	11	6.8E-11	2.6E+01	N/A	--	N/A	--	N/A	--	6.8E-11	2.6E+01	N/A	--	6.8E-11	2.6E+01	6.8E-11	2.6E+01
SHPGC	11	1.6E-11	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	1.6E-11	2.6E+01	1.6E-11	2.6E+01
SHPHC	11	1.6E-11	2.6E+01	N/A	--	1.6E-11	2.6E+01	N/A	--	N/A	--	1.6E-11	2.6E+01	1.6E-11	2.6E+01	N/A	--
SHFVC	11	1.6E-11	2.6E+01	N/A	--	1.6E-11	2.6E+01	N/A	--	N/A	--	N/A	--	1.6E-11	2.6E+01	1.6E-11	2.6E+01
SHQGC	11	1.2E-11	2.6E+01	N/A	--	1.2E-11	2.6E+01	N/A	--	N/A	--	N/A	--	1.2E-11	2.6E+01	1.2E-11	2.6E+01
SHQVC	11	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	1.2E-11	2.6E+01	1.2E-11	2.6E+01
SHRGC	11	2.9E-11	2.6E+01	N/A	--	2.9E-11	2.6E+01	N/A	--	2.9E-11	2.6E+01	N/A	--	2.9E-11	2.6E+01	2.9E-11	2.6E+01
SHRVC	11	2.9E-11	2.6E+01	N/A	--	2.9E-11	2.6E+01	N/A	--	2.9E-11	2.6E+01	N/A	--	2.9E-11	2.6E+01	2.9E-11	2.6E+01
Forklift collision; detonation occurs																	
SHDHC	12	5.4E-16	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	5.4E-16	2.6E+01	5.4E-16	2.6E+01	N/A	--
SHCGC	12	2.6E-16	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	2.6E-16	2.6E+01	N/A	--
SHCHC	12	2.6E-16	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	2.6E-16	2.6E+01	N/A	--	N/A	--
SHMVC	12	4.0E-16	2.6E+01	N/A	--	N/A	--	N/A	--	4.0E-16	2.6E+01	N/A	--	4.0E-16	2.6E+01	4.0E-16	2.6E+01
SHPGC	12	8.6E-17	2.6E+01	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	8.6E-17	2.6E+01	8.6E-17	2.6E+01
SHPHC	12	8.6E-17	2.6E+01	N/A	--	8.6E-17	2.6E+01	N/A	--	N/A	--	8.6E-17	2.6E+01	8.6E-17	2.6E+01	N/A	--
SHFVC	12	8.6E-17	2.6E+01	N/A	--	8.6E-17	2.6E+01	N/A	--	N/A	--	N/A	--	8.6E-17	2.6E+01	8.6E-17	2.6E+01
SHQGC	12	6.8E-17	2.6E+01	N/A	--	6.8E-17	2.6E+01	N/A	--	N/A	--	N/A	--	6.8E-17	2.6E+01	6.8E-17	2.6E+01
SHQVC	12	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	N/A	--	6.8E-17	2.6E+01	6.8E-17	2.6E+01
SHRGC	12	1.7E-16	2.6E+01	N/A	--	1.7E-16	2.6E+01	N/A	--	1.7E-16	2.6E+01	N/A	--	1.7E-16	2.6E+01	1.7E-16	2.6E+01

See notes at end of table.

TABLE 5-21 (Continued)

CONTINUED STORAGE OPTION - HANDLING ACCIDENTS RELATED TO SURVEILLANCE AND MAINTENANCE
(PER PALLET- OR CONTAINER-YEAR)

ACCIDENT FREQUENCIES

SCENARIO	NO.	ANAD FREQ	RANGE FACTOR	APG FREQ	RANGE FACTOR	LBAD FREQ	RANGE FACTOR	NAAP FREQ	RANGE FACTOR	PBA FREQ	RANGE FACTOR	PUDA FREQ	RANGE FACTOR	TEAD FREQ	RANGE FACTOR	UMDA FREQ	RANGE FACTOR
SHRVC	12	1.7E-16	2.6E+01	N/A	--	1.7E-16	2.6E+01	N/A	--	1.7E-16	2.6E+01	N/A	--	1.7E-16	2.6E+01	1.7E-16	2.6E+01

NOTE: Scenarios 8 through 12 are events per pallet or container. The events per pallet- or container-year values are classified.

The trends indicated by the frequency results are as follows:

Externally-Induced Events

1. Tornado and high wind

   a. Munitions stored outdoors or in warehouses are generally more susceptible to tornado strikes. APG, PBA, NAAP, TEAD and UMDA have warehouses. PBA and NAAP are in Tornado Zone I while APG is in Tornado Zone II (Zone I has the highest tornado frequency). TEAD and UMDA are in Tornado Zone III.

2. Meteorite strike

   a. Munitions stored in warehouses are more susceptible to meteorite strikes. Since fire is generally present, a meteorite strike may involve the entire warehouse inventory.

3. Aircraft crashes

   a. Munitions stored outdoors are generally more susceptible to these events. APG, TEAD and PBA have ton containers stored outdoors. However, the aircraft crash probabilities at APG and PBA are relatively higher than the other sites.

   b. Igloos provide minimal protection from direct crashes of large aircraft. The accident becomes more serious when burstered munitions are involved.

c. Large aircraft crash frequencies at APG, LBAD, and TEAD greatly increase for the air option because of the additional landings and takeoffs at these sites.

4. Earthquakes

a. Earthquakes, particularly in high seismic locations such as TEAD, could cause stacked munitions to be punctured. However, the probability of having a probe present inside an igloo is quite low.

b. Detonations due to earthquake-induced drops are at least two orders of magnitude less likely than punctures.

c. There is a significantly high frequency earthquake-induced agent releases to munitions stored in warehouses at NAAP, TEAD, and UMDA.

Leaker-Related Events

1. Forklift drop accidents can occur more frequently than forklift tine punctures.

2. Use of a lifting beam instead of a tine leads to an order of magnitude decrease in drop frequency.

5.5. UNCERTAINTY ANALYSIS

5.5.1. Overview

The frequency results presented in Tables 5-16, 5-17, and 5-18 are median values. The values shown in the range factor column represent the ratios of the 95th percentile values to the median values. The range factors vary from 10 to almost 100. The tornado frequency results have the highest uncertainties largely because of the difficulty to accurately model the probability that the missile will be in the proper orientation to penetrate the munition and actually how many missiles per square foot of wind will be present. The ability to model low-impact detonations also lead to large uncertainties in the final results. The data available are scarce and sometimes not directly applicable to the scenario being analyzed.

5.5.2. Error Factors

In those cases where sufficient information exists to determine the upper- and lower-bound values, the error factor was derived by assuming that the upper-bound value is equivalent to the 95th percentile. The engineer's best estimate is taken as the median value based on the properties of the lognormal distribution. This choice is rather conservative since the mean value of the resulting distribution becomes larger than the best estimate or recommended value.

In many cases, however, the data sources were limited. Therefore, the assignment of error factors was entirely based on engineering judgment, taking into consideration the important parameters which may influence a particular variable. The generic guidelines for the uncertainty assessment is shown in Table 5-19.

5.5.2.1. Tornado Sequence Uncertainties. The frequency of the initiating event itself (i.e., tornado wind of sufficient intensity to generate missiles occurs) is assigned an error factor of 10 per Table 5-19. The conditional probability of a missile hitting the structure and penetrating the munition is assigned an error factor of 50. As explained in Section 5.2.1.1 (Eq. 5-2), this event is the product of four variables. The uncertainty is largely due to the variable D_e which is the number of missiles per square foot of wind. The conditional probability of a burstered munition detonating when hit by a missile is assigned an error factor of 2.

5.5.2.2. <u>Meteorite Strike Sequence Uncertainties</u>. The frequency of a meteorite strike is assigned an error factor of 10. The conditional probability of a meteorite penetrating and rupturing the munition is the product of (1) fraction of stone and iron meteorites capable of penetrating the target; (2) target area; and (3) spacing factor. This event is assigned an error factor of 10. The uncertainty is largely due to the fraction of stone and iron meteorites capable of penetrating the structure.

5.5.2.3. <u>Aircraft Crash Sequence Uncertainties</u>. The aircraft crash frequency is assigned an error factor of 10. Aircraft crash accident sequences with or without fires (from impact) have been considered. For this reason no uncertainties were assigned to either the probability of having a fire (0.45) or no fire (0.55). The uncertainties associated with the structural damage (i.e., igloo or warehouse) given an aircraft crash are given in Table 5-8. For events with probabilities greater than 0.1 the uncertainties assigned followed the guidelines given in Table 5-19.

5.5.2.4. <u>Earthquake Sequence Uncertainties</u>.

<u>Storage Igloos</u>

The initiating event, earthquake occurs, is assigned an error factor of 10. The conditional event, munition punctured given drop, is assigned an error factor of 5. The puncture probability is a function of drop height, weight and presence of a probe of sufficient length and density. The uncertainty is largely due to the last variable. Note also that no uncertainty from errors with the models has been considered since this is beyond the state-of-the art of present day uncertainty analysis.

5.5.2.4. Earthquake Sequence Uncertainties.

Warehouse Storage

Event 1: Earthquake Occurs

The initiating event frequency is assigned an error factor of 10.

Event 2: "K" Warehouses Damaged by Earthquake

Uncertainty factors for values above 0.1 are taken from Table 5-22. For probabilities between 0.01 and 0.1 an uncertainty factor of 3 is recommended. Probabilities below 10^{-2} is assigned an uncertainty factor of 3. The uncertainty distribution in each case is lognormal.

5.5.2.5. Handling Accident Sequence Uncertainties. All initiating events associated with munitions handling (i.e., drops, collisions, forklift tine punctures) were assigned an error factor of 10. The conditional probability of puncturing the munitions given any one of the initiating events is assigned an error factor of 3. The probability of causing a low-impact detonation (i.e., drop from 6 ft or lower) is assigned an error factor of 10.

5.6. REFERENCES

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6. QUANTIFICATION BASES

6.1. HANDLING ACCIDENT DATA

All initiating event frequency accidents, except for forklift collisions, were derived from the human reliability analysis and are discussed in Section 6.2.

The forklift collision accident frequency was derived from Ref. 6-1. In Ref. 6-1, accidents were defined to include incidents that result in fatalities, injuries, or property damage. The basic truck accident rate is 2.5×10^{-6} accidents/mile. From Table II of Ref. 6-1, the percent of accidents leading to collisions with trucks, autos, and stationary objects and overturns is 89.35%. Table III of Ref. 6-1 also show that 50% of all accidents occur at speeds of 30 to 40 mph.

To convert the basic rate to accidents per operation, the operator's exposure time in the highway is determined. If the operator was traveling at 35 mph, the exposure time is 1.7 min.

In order to apply this information to forklift collision accidents, the following were assumed:

1. The total operator exposure time during the forklift operation is 10 min. This includes the lifting of munitions from the stack, moving them to another area, and unloading them.

2. The time to travel from one point to another is assumed to be one-third of the total time, or 3.3 min.

3. Forklift collisions will occur at speeds no greater than 40 mph (i.e., two forklifts traveling at 20 mph).

Therefore, forklift collision accident rate is:

$$2.5 \times 10^{-6} \times 0.893 \times \frac{3.3}{1.7} = 4.3 \times 10^{-6}/\text{operation} \quad .$$

This median value is assigned an error factor of 10 on the basis that the data is only for 6 yr and there may be other unreported incidents more directly related to forklift operations.

Reference 6-1 also indicates that 25% of fires result from collision-type accidents. It is not evident from the data if fire from collision is directly proportional to truck speed. Our analysis assumes that it is. Therefore, the data was modified as follows:

$$\text{Probability of fire} = 0.25 \times 0.29 = 0.0725 \quad ,$$

where the factor 0.29 represents the percent of collisions occurring at less than 20 mph.

6.2. HUMAN FACTORS DATA

Human-error probabilities were quantified for use in the handling scenarios using the approach to human-error estimation described in NUREG/CR-1278 (Ref. 6-2), probabilities of human errors were estimated based on several performance-shaping factors such as munition configuration, handling operation, clothing level, and crew size. These factors are identified in the discussions that follow on the derivations of each estimate. Table 6-1 lists the error probabilities estimated for puncturing or dropping a munition based on each of these factors. These error probabilities will be incorporated into the handling scenarios as shown in the data tables in Table 6-2.

1. <u>Puncturing a munition</u>. The basis for the error estimates is taken from Section 4.4.2 of Ref. 6-3 (pages 4.4 through 4.26). This reference gives 4×10^{-5} as a data-based estimate of the probability of handling errors using forklifts for the rocket stockpile. This is an estimate of the likelihood of an error in forklift operation that potentially could lead to a warhead rupture while attempting to isolate a leaking rocket inside the storage igloo.

   That estimate is based on conditions that do not entirely represent those assumed by this study; namely, that a three-man crew will perform all forklift operations. In this study, it is assumed that a two-man crew will perform all forklift operations--one driving the forklift and one guiding forklift and munition position from the ground. This means that the data-based estimate may not represent the probability of forklift-handling errors expected under actual conditions. Therefore, this estimate was revised to 1×10^{-4} to account for a smaller crew. The revised estimate of 1×10^{-4} is the probability that one or both members of a two-man crew will err such that the forklift tine is in a position to puncture a

TABLE 6-1
HUMAN ERROR PROBABILITIES PER HANDLING OPERATION

Error Type For Munition Configuration	Handling Operation for Clothing Type: Level A or DPE — Hand Carry[a]	Level A or DPE — Forklift	Levels B, C, and D (Mask, Gloves, and Boots) — Hand Carry[a]	Levels B, C, and D (Mask, Gloves, and Boots) — Forklift	Levels E and F (Street Clothes, Mask Slung) — Hand Carry[a]	Levels E and F (Street Clothes, Mask Slung) — Forklift
Tine Carried						
Drop	6.0×10^{-4}	3.0×10^{-4}	3.0×10^{-4}	1.5×10^{-4}	6.0×10^{-5}	3.0×10^{-5}
Puncture	NA	1.0×10^{-4}	NA	5.0×10^{-5}	NA	1.0×10^{-5}
Beam Carried						
Drop	NA	3.0×10^{-5}	NA	1.5×10^{-5}	NA	3.0×10^{-6}
Puncture	NA	NA	NA	NA	NA	NA

(a)Hand-carry operations involve one weapon at a time.

TABLE 6-2
DATA BASE FOR LEAKERS IN STORAGE

Event		Frequency or Probability	Reference
Munition develops a leak during storage (Scenario SL1):			
Bomb	(TEAD)	7.5E-5 per yr	Ref. 5-20
	(UMDA)	4.5E-4 per yr	
4.2-in. mortar	(ANAD)	2.8E-7 per yr	
	(PUDA)	1.0E-6 per yr	
	(TEAD)	7.0E-6 per yr	
105-mm cartridge	(ANAD)	2.8E-7 per yr	
	(PUDA)	1.0E-6 per yr	
	(TEAD)	7.0E-6 per yr	
Ton container		5.9E-6 per yr	
Mine	(ANAD)	9.0E-6 per yr	
	(PBA)	1.1E-6 per yr	
	(TEAD)	2.5E-4 per yr	
	(UMDA)	3.1E-4 per yr	
Projectile	(ANAD)	4.9E-6 per yr	
	(LBAD)	9.3E-6 per yr	
	(PUDA)	5.0E-6 per yr	
	(TEAD)	8.1E-5 per yr	
	(UMDA)	6.2E-5 per yr	
Rocket	(ANAD)	6.1E-5 per yr	
	(LBAD)	4.3E-5 per yr	
	(PBA)	9.1E-7 per yr	
	(TEAD)	1.3E-3 per yr	
	(UMDA)	1.8E-4 per yr	
Spray tank		9.8E-5 per yr	
Forklift tine accident (SL2)		1.0E-4 per oper.	Ref. 5-17
Munition punctured given tine accident:			
Bomb		1.29E-2	Ref. 5-2
4.2-in. mortar		3.68E-2	
105-mm cartridge		3.90E-3	
Mine		7.07E-2	
Projectile		5.00E-2	

TABLE 6-2 (Continued)

Event	Frequency or Probability	Reference
Rocket	2.63E-1	
Spray tank	1.53E-2	
Munition dropped during leaker isolation (SL9):		
Pallet and bulk (B, S)	3.0E-4	Human Reliability Analysis (Ref. 5-17)
Single (C,D,M,P,Q,R)	.0E-4	
Ton container (K)	3.0E-5	
Munition punctured given drop:		
Bomb (pallet)	4.72E-4	Ref. 5-2
(single)	1.62E-4	
4.2-in. mortar (pallet)	1.24E-4	
(single)	0.0	
105-mm cartridge (pallet)	2.71E-5	
(single)	0.0	
Ton container	1.55E-3	
Mine (pallet)	9.27E-5	
(single)	4.08E-5	
Projectile (pallet or single)	0.0	
Munition detonates given drop:	1.6E-8/munition	Ref. 5-2
Forklift collision leads to drop of munitions	4.3E-6/oper.	Ref. 5-12 and Ref. 5-2
Collision results in fire	0.0725	Ref. 5-12
Fire contained:		
Burstered (4 min)	0.5	Engineering judgement
Nonburstered (30 min)	1.00	Fuel will be limited so as limit fire to less than 10 min

munition. (This puncture probability applies to those cases in which forklift tines are used to lift munitions; it includes palletized munitions and spray tanks in overpacks.)

Another difference is that the original estimate from Ref. 6-4 (4×10^{-5}) was based on operations with leaking rockets. This meant that it assumes that the crew is wearing Level A protective clothing. If the same forklift operations are performed in less strenuous circumstances (i.e., if a lower level of protective clothing is worn), the error probability estimate can be lowered. Here, it has been lowered to 5×10^{-5} for the case of the operators' wearing partial protection (masks, gloves, and boots) and to 1×10^{-5} for the case of their wearing minimal protection (street clothes, with masks slung).

2. <u>Dropping a munition</u>. For palletized munitions and spray tanks in their overpacks, human-caused drops from forklifts are judged to be three times as likely as punctures caused by operating the same kind of forklift. The error-probability estimates are 3×10^{-4}, 1.5×10^{-5}, and 3×10^{-5} for dropping a munition from a forklift tine when wearing Level A, Level C, or Level F protective clothing, respectively.

Because of unwieldy pallet and overpacked spray tank loads, and because it is assumed that forklift-tine loads are likely to be carried at higher speeds than are forklift-beam loads, the likelihood of a ton container or other beam-carried loads being dropped because of human error is judged to be an order of magnitude lower than that of a tine-carried load being dropped. These are estimated to be 3×10^{-5}, 1.5×10^{-6}, and 3×10^{-6} for protective clothing Levels A, C, and F, respectively.

For hand-carried munitions, munition drops are estimated to be twice as likely as drops of tine-carried load from forklifts. The estimated probabilities of dropping a hand-carried munition when wearing Levels A, C, and F protective clothing are 6×10^{-4}, 3×10^{-4}, and 6×10^{-5}, respectively. (Loads carried by forklift beams are never hand carried.)

These probability estimates are the likelihood of an error per handling operation. A single forklift operation may involve a single munition such as a spray tank or as many as 48 weapons on a pallet, while a single hand-carry operation will always involve only a single munition.

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7. AGENT RELEASE CHARACTERIZATION

Section 7.1 describes the approach used in this study for analyzing the agent release for the various accident conditions. Application of the approach to the accident sequences analyzed in the continued storage option is discussed in Section 7.2.

The consequences of an agent release event are strongly dependent on agent type, amount of agent release, and the mode and duration of the release. Agent dispersion and subsequent effects will be calculated in a separate study using a computer program called D2PC (Ref. 7-1) that embodies an analytical model for calculating agent dispersion under different meteorological conditions. Feedback from these consequence calculations helped to guide the release characterization.

7.1. RELEASE ANALYSIS APPROACH AND BASES

7.1.1. Approach

The approach formulaton was aided by a systematic review of the mechanisms involved in expelling agent from its normal confinement. The analyses performed by Arthur D. Little for the M55 rockets (Refs. 7-2 through 7-6) were partially applicable, and similar assumptions as appropriate were made for this analysis. Additional calculations were performed in this study to determine the quantity of agent released to the environment for plant operation accidents involving munitions other than the M55 rockets.

For the accident scenarios that involve agent still confined in the munition, the agent release is dependent on the munition's mechanical and thermal failure thresholds, and the behavior of the explosives and propellants during the accident scenarios. These are discussed in the following sections. Once it was determined that the agent could be released from its normal confinement, calculations were performed to determine the amount of agent released and the possible paths by which the agent could enter the atmosphere.

7.1.2. Mechanical Failure Release

Munition failures result when sufficient forces are generated during accidents. A discussion of the munition failure thresholds is given in Appendix F. The failure thresholds of interest are:

1. Mechanical failure of the agent containment due to impact, crush or puncture.
2. Detonations initiated by impact or fire.
3. Thermally induced hydraulic rupture of the agent containment.

7.1.2.1. Impact Failure. The threshold for impact failure is given in terms of velocity of impact against a nonyielding object, or the equivalent drop height. When the impact failure threshold is reached, it is assumed that the onset of failure begins. In the case of an accident involving more than one munition, e.g., a pallet drop or a forklift collision, every munition does not experience the effect of impacting a nonyielding surface. At the threshold point, it is assumed that at least one munition has experienced failure. It was further assumed that the number of munitions that experience failure is a function of the kinetic energy involved in the accident.

The impact velocity required to initiate failure varies from 35 mph for rockets (drop height of 40 ft) to 50 mph for projectiles (drop height of 120 ft). The expected impact velocity (or drop height) for some accidents is:

Accident Type	Impact Velocity of Drop Height
Pallet drop during handling	6 ft
Forklift collision	5 mph

In view of the above, failure due to impact is not considered to be a significant contribution for handling accidents, i.e., other failure mechanisms dominate.

7.1.2.2. Crush Failure. Crush forces are static forces completely independent of velocity. Crush forces may arise from a building collapse due to an earthquake.

Crush thresholds are defined for a single munition and for a pallet of munitions. When the crush threshold for pallets is exceeded, it was conservatively assumed that all munitions in the pallet will fail.

A linear relationship for the number of units that would fail due to crush was assumed as follows:

$$n = \frac{F}{F_o} \quad , \tag{7-1}$$

where F = crush force available in the accident,

F_o = crush force threshold for the palletized munition.

At $n = 1$, all the munitions in one pallet have failed. The available force in an accident can be the weight of a vehicle, the weight of a building collapse, or the weight of any large object that can fall on the munitions.

The accident scenarios that are capable of generating forces sufficiently high to produce crush involve external events where many pallets may be involved in the accident. Thus, it is possible that more than one pallet can fail. For example, the crush threshold for a rocket pallet containing 15 rockets is 43,400 lb. If the weight of an object is 100,000 lb, Eq. 7-1 predicts a failure quantity of 2.3. This corresponds to 2.3 pallets, or about 34 rockets being crushed. If the available crush force is less than the failure threshold for a single munition, then naturally, no munitions fail.

Equation 7-1 is conservative because it assumes that the total available load arising from an accident is concentrated in the most efficient way to crush the munitions. If the load was uniformly distributed over many pallets, fewer or no failures would occur.

7.1.2.3. Puncture Failure. The puncture threshold is defined in terms of the ratio of velocity to radius of curvature assuming the munition (or pallet) impacts an unyielding slender object or probe. Generally, the failure threshold for puncture is the lowest of the three mechanical failure thresholds. The number of failures that can occur in an accident is dependent on the number of probes present. If the puncture failure threshold is exceeded, it is assumed that one probe will fail one munition.

7.1.2.4. Liquid Spills and Evaporation. Once mechanical failure occurs, the munition agent inventory may be able to spill out on the ground or water. For forktine punctures, the puncture is assumed to consist of a 3-in. diameter hole just below the munition centerline. The amount and time of spill is calculated to be that which can drain by gravity out of the hole. Impact, crush and probe punctures are assumed to result in the spill of the entire munitions inventory.

If the spill occurs outdoors during leaker handling, the release analysis ends with the determination of the type and mass of liquid agent spilled and type of surface where the spill occurs. This information is sufficient input for calculation of atmospheric dispersion by the D2PC computer program (Ref. 7-1). All liquid spills during handling or ground transport are assumed to occur on a hard, flat impervious surface such as level concrete or asphalt. The evaporation of the spill is calculated by the D2PC program by calculating the maximum puddle area and the corresponding evaporate rate.

If the spill occurs indoors, the release analysis in this report extends to the time dependent rates of evaporation. In general, the D2PC program was applied to calculate the evaporation rate based on the type and mass of agent spill and considering any confinement of the liquid puddle or pool. The D2PC general equation for evaporation of a spill over a floor area corresponding to a liquid pool depth of 1/32 in. relates the time t to evaporate the entire spill inventory M (pounds) in terms of a power function of M and two coefficients a and b. The equation is

$$t = aM^b \quad , \tag{7-2}$$

where t = time in thousands of minutes,
a, b = constant for agent GB ($a = 0.79$, $b = 0.253$),
a, b = functions of M for agents H and VX.

The area (ft^2) corresponding to the spill M (lb) and pool thickness 1/32 in. is 5.91 times M. For restricted pool areas, the equation must be modified. This equation and coefficients a and b are based on data from the Army derived from the computer program D2PC output.

For a given accident sequence the spill will generally not evaporate to completion because human intervention will mitigate the spill by covering it with foam or some other means. In such a case, an evaporation rate is calculated and applied until the time estimated for mitigation or cleanup of the spill.

From Eq. 7-2, the hourly evaporation rate is

$$m_{ev} = \frac{1}{a} M^{1-b} \frac{60 \text{ min}}{10^3 \text{ min}} \quad , \tag{7-3}$$

where m_{ev} has units of lb/h. This equation applies whenever the 1/32-in. deep spill pool area, which from the agent density is about 6 ft^2 for each lb of spill, is smaller than the actual confined pool area (floor or sump).

Where a sump is present, the following procedure is used to calculate evaporation. Initially, the spill is assumed to wet the entire sloped floor area. Thus, Eq. 7-3 issued for a 10 min time period without modification for pool area, unless the 1/32-in. deep pool area is larger than the actual floor area. Modification consists of limiting M in Eq. 7-3 to the mass of a 1/32-in. layer of agent over the actual floor area. After 10 min, the evaporation rate is assumed to be limited by the sump horizontal cross sectional area until the assumed mitigation/cleanup time when it drops to zero. Such limitation amounts to modifying M in Eq. 7-3 to the mass of a 1/32-in. layer in the sump.

7.1.3. Detonations

The burstered munitions incorporate proven design features to preclude accidental detonation during routine handling. The impact threshold for initiating detonation, approximately 160 mph (see discussion in Appendix F), is well above the potential impact velocity for all accidents. When a munition is subjected to an impact velocity greater than the detonation threshold velocity, there is still a low probability of detonation, but it is possible. Data does not exist to develop a meaningful relationship for predicting the number of detonations that could occur given an aircraft crash into a munitions storage area. This rationale is that, given a stack of munitions pallets in storage the munitions in the first row would absorb most of the impact energy. These munitions could detonate. The others would then be subjected to the energy of the detonations, as well as part of the energy of the aircraft crash. It is known that the detonations do not propagate, but it is assumed that many of them would rupture. This logic was applied to all the aircraft crash scenarios and a general result was reached. The conservative estimate is that:

1. Fifteen percent of the munitions involved in the crash detonate.

2. Seventy percent of the rupture and release their agent content.

3. Fifteen percent are scattered but remain intact.

For impacts of burstered munitions in pallets, if a single munition detonation occurs it is assumed to rupture each surrounding munition in the pallet. A centrally located munition, which has the largest number of surrounding units, is conservatively assumed to be the one which detonates, even though it is less likely to detonate at this location thanat the end. For projectiles, cartridges, and mortars, the number of adjacent munitions ruptured is five.

For rockets and mines only, the detonation of more than one munition was calculated to be credible for certain pallet impacts. In such cases, two rockets detonate, rupturing 13 adjacent rockets. Or, three mines detonate rupturing 15 adjacent munitions.

7.1.4. Fire Release

Munitions subject to fire can fail due to thermally initiated detonations or due to hydraulic rupture. It is assumed that fires in direct contact with burstered munitions will be left unattended and allowed to burn until all combustible materials are consumed. Thus, bursters will detonate. Some neighboring munitions will fail due to the detonation. The failed munitions will spill combustible agent which will further fuel the fire. The fire will spread, leading to more detonations, and so on.

Tests at GA on 4.2-in. mortar projectiles and 8-in. projectiles showed that a detonation of a munition in a close packed array will cause the munitions adjacent to the detonated munition to break and spill their agent (Ref. 7-7). Other munitions not in direct view of the detonated munition were disheveled, but remained intact. Thus, one detonation is not sufficient to break all the munitions involved in the accident. A chain reaction must take place. The bursters in the neighboring munitions broken by a detonation will be subjected to more rapid heating than those of an intact munition. These bursters will detonate at a critical temperature, but it is assumed that detonation of a drained munition will not contribute to the agent release.

Based on the test results described above, it is inferred that all munitions in direct view of a munition detonation would be broken. In a rectangular array, typical for the munition storage configurations, this results in an agent release fraction of 1/9 due to detonation and 8/9 as a liquid spill. An irregular array, such as would exist after the first detonation, could result in a larger release fraction due to detonations. Therefore, it is assumed that 25% of the agent release is due to detonations for scenarios involving fire and detonations.

It is assumed that fires involving nonburstered munitions will always be fought. However, when an accident involves a large fire, the first priority may be to contain the fire and prevent its spreading into unaffected areas. For conservatism, a large fire involving nonburstered munitions was treated as in the case for burstered munitions, i.e., all combustible materials involved in the accident are consumed. Whether burstered or nonburstered munitions are involved, large fires were assumed to be confined to one building, one railcar, or one truck, as appropriate.

Agent that is burned is basically destroyed, but the destruction is usually incomplete. A previous analysis (Ref. 7-8) indicated that the recovery of undecomposed agent from fires is 2.5% for GB and 0.2% for VX. The analysis was based on tests at Dugway Proving Ground (Refs. 7-9 and 7-10) in which a mock-up igloo with 11 pallets of rockets containing GB was allowed to burn to completion. The unburned GB vapor was measured by a grid of detectors surrounding the fire at 30 m distance and extending 30 m high. Actual test measurements were made for GB, and the results for VX were derived by extrapolation based on the boiling temperature, thermal decomposition temperature and volatility of VX relative to GB.

Although the references cited above provide a quantitative data point on the behavior of agent in a large fire involving an igloo or a transport vehicle, there are several reasons to increase the predicted agent release fraction for fires. These are:

1. The analytical procedure for detecting agent during the test yielded small quantities of agent distributed over a large number of detectors. The samples were analyzed by the dianisidine-peroxide method. The sensitivity of these measurements is expected to be marginal considering the short time available for sampling the gas cloud as it passed through the detection grid. Therefore, it is possible that a significant amount of agent vapor was not detected during the test.

2. The rockets contain a large amount of propellant, which in turn contains its own oxidizer. The propellant burns very quickly and tends to produce a hot fire, even when the fire is limited by the amount of oxygen present. Fires involving other munitions may burn slower and at a lower temperature, which would promote a higher fraction of undestroyed agent.

3. In one simulated test of an igloo fire (Ref. 7-10) four rockets were launched out of the igloo. One of them traveled 1300 ft away from the igloo. None of them detonated upon impact, but they all broke open and spilled agent onto the ground. When one adds the liquid spill of the four rockets that escaped from the igloo to the 2-1/2% agent vapor recovered, the total agent release from the event is 4.9%.

4. The analytical extrapolation to determine the recovery fraction for VX is not documented. Further, the uncertainty of an extrapolation in a complex thermal-chemical rate process is considered to be large. Although the chemical properties of VX and GB suggest that the recovery fraction for VX should be much less than GB, the conclusion that the recovery of VX would be 6% times the recovery of GB as stated in Ref. 7-10 is viewed with skepticism. Therefore, a more conservative value of 25% was assumed for the recovery factor of VX versus GB. Similarly, the chemical properties of HD suggest that an analytical extrapolation for the recovery of HD would also be less than GB, but greater than VX. Therefore, a value of 50% was assumed for the recovery factor of HD versus GB.

In view of the above discussion, the release fraction for unburned agent GB vapor in all fire scenarios was assumed to be 10%. This provides a factor of two over the 4.9% combined liquid plus vapor measured in the test to allow for uncertainties in the test measurements and uncertainties in the liquid agent that escapes the fire. The corresponding release fractions for HD and VX are assumed to be 5% and 2-1/2%, respectively. These release fractions are not considered as over conservatism. The main conservatism arises from the assumption that all the agent inventory is involved in the fire, and no credit is taken for the possibility that the fire might be extinguished before all combustible materials are consumed.

7.1.5. Release Duration

The accident durations assumed for this risk analysis were chosen to conservatively define a time for terminating most accidents identified in this analysis. In the scenarios involving liquid spills, the accident is terminated when the decontamination team has successfully terminated evaporation of agent vapor into the atmosphere. Army experience in handling and moving chemical munitions indicates that may of the agent spills could be cleaned up much quicker than the times assumed herein. However, since many accidents are rate events and have not occurred in the Army experience to date, conservative times for the accident durations have been applied.

The agent release for an evaporative spill is directly proportional to the release duration. Therefore, to be conservative, the release durations were estimated on th- high side. The release durations assumed are:

1. For agent spills occurring during handling caused by human or equipment malfunction, the release duration was assumed to be 1 h.

2. For agent spills arising from an aircraft crash with no fire, the release duration was assumed to be 4 h.

3. For severe external events, e.g., earthquake, tornado, airplane crash, the evaporation time was assumed to be 6 h.

Table 7-1 lists the times assumed for agent release for the accident scenarios involving fire and/or detonations.

The approach to deriving the assumed release durations was to group the accident scenarios with fire or detonations into sets with similar characteristics, then estimate a release time ranging from 10 min to

TABLE 7-1
AGENT RELEASE DURATION FOR ACCIDENTS INVOLVING FIRE AND DETONATION

Event	Agent Release Duration (min)	Type of Event
Fire only - no detonations	10	Handling vehicle collision
	60	Aircraft crash, meteorite strike, earthquake
Fire with detonation	20	Aircraft crash, earthquake
	60	Meteorite strike
Detonations only	Instantaneous	Aircraft crash

1 h. For accidents involving a large fire, it was assumed that all of the agent present ultimately becomes consumed or released as vapor. The conservative approach for these cases is to assume a shorter duration than expected because a given release to the atmosphere is more lethal when distributed over a shorter time interval. Factors which influence the choice of time periods are discussed below.

There are three possible combinations of scenarios involving fire and/or detonations:

1. Detonations only.
2. Fire and detonations.
3. Fire only.

7.1.5.1. Detonations Only. The scenarios that fall into this category involve a high velocity impact, such as an aircraft crash, or spurious detonation arising from undue forces that are part of the accident scenario, e.g., dropping a pallet. It is known that the detonations do not propagate. Therefore, the release from detonations is assumed to occur instantaneously.

7.1.5.2. Fire and Detonations. These events are associated with external storage accidents. For some events, there is a source of external fuel, e.g., an airplane crash. In these scenarios, the detonations are propagated by the fire, and concurrently the detonations allow additional munition failures that further fuel the fire. The overall result is a violent conflagration. The total duration of the accident may be an hour or more; however, for conservatism, the duration of the agent release is assumed to be 20 min. The scenarios not included in the 20-min assumption involve a meteorite strike into a storage igloo or into a temporary storage area. In this case, there is no source of external fuel, although the scenario does assume that fire is initiated, and detonations are propagated by the fire until all combustible materials are consumed. Because the meteorite fire starts out relatively localized and without external fuel, the release duration for the meteorite strike is assumed to be 1 h.

7.1.5.3. Fire Only. Events involving fire only occur in some storage accidents. For events associated with handling the amount of agent involved in the fire is relatively small. The exposed agent is allowed to burn to completion, and the release duration is assumed to be 10 min. Accidents involving external events involve large quantities of agent. Therefore, these accidents present a less difficult situation to control. The agent release duration for these events was assumed to be 1 h.

7.2. APPLICATION TO ACCIDENT SEQUENCES

This section illustrates the application of the release methodology to determine agent releases for the specific accident sequences. It is not intended to encompass all sequences. Appendix I presents the agent releases for all sequences. Table 7-2 gives the munition and pallet inventories. Details of all agent release calculations are contained in the supporting calculations for this risk assessment, Ref. 7-11.

7.2.1. Warehouse Storage Release During Earthquakes

There are three sites with stored, nonburstered munitions in warehouses. These are:

1. UMDA - ton containers with agent HD stored in two warehouses.

2. NAAP - ton containers with agent VX stored in one warehouse.

3. TEAD - spray tanks with agent VX stored in two warehouses.

Only spray tanks and ton containers are stored in warehouses, none of which contain agent GB. Based on their impact characteristics, the ton containers are predicted to be able to be crushed or breached by the kinetic energy of a falling I-beam if the warehouse structure is damaged. Each I-beam has sufficient energy to crush one ton container but not two. Thus, the maximum number of ton containers crushed per warehouse is five, since there are that many I-beams in the warehouse roof. For similar reasons, the maximum number punctured is taken to be five per warehouse.

Spray tanks are stored in overpacks and, based on structural calculations, are not expected to be breached by the falling I-beams.

TABLE 7-2
INVENTORY DATA FOR MUNITIONS AND PALLETS

Munition/Agent Type	Munition Inventory (lb)	No. Munitions Per Pallet
Bomb		
GB	220.0	2
Mortar		
H	6.0	48
105 cartridge		
GB	1.6	24
H	3.2	24
Ton container		
GB	1500.0	1
H	1700.0	1
VX	1600.0	1
Mine		
VX	10.5	36
155 projectile		
GB	6.5	8
H	11.7	8
VX	6.0	8
8-in. projectile		
GB	14.5	6
VX	14.5	6
Rocket		
GB	10.7	15
VX	10.0	15
Spray tank		
VX	1356.0	1

Consequently, the mechanical breaching of spray tanks due to an earthquake is not considered a credible event. If a fire lasts beyond 30 min, spray tanks may fail due to the unsuppressed fire. Thus, for spray tanks, only one type of release is considered, namely burning of one or two warehouse inventories due to fire beyond 30 min. The release fraction due to unburnt VX agent in this case is 2.5%, as in other accident scenarios.

For ton containers, three release types were considered:

1. Evaporation of agent spilled due to mechanical breach of one to five containers per warehouse.

2. Burning of agent spilled from breached containers.

3. Burning of the entire inventory in the warehouse, starting at 30 min.

The evaporative release rate is not limited by the floor area, which is tens of thousands of square feet per warehouse. Thus, the evaporative release rate, m_{ev}, is given by Eq. 7-2. For 10-ton containers with agent HD, M = 17,000 lb and a ≈ 451 and b ≈ 0.1. Thus, m_{ev} = 0.85 lb/h for 10 containers. This rate of HD release is negligible. Therefore, evaporative release of spilled HD from breached munitions is negligible. For agent VX, the maximum number of breached ton containers is five. In this limiting case, M = 8000 lb and a ≈ 49,000, b ≈ 0.12. Thus, m_{ev} = 0.003 lb/h for five breached containers. This rate of release is negligible.

The second and third types of releases involve burning of spilled agent from breached containers or burning of all ton containers due to a lack of fire suppression. For these cases, the release consists of the product of the appropriate inventory and the fire release fraction, F. Here, F = 0.025 for agent VX and F = 0.05 for agent HD, consistent with data described above. No credit is taken for agent vapor retention by the warehouse building, even if it is not structurally damaged by the earthquake, because it is not designed with a containment function.

As described in Section 5, an event tree was analyzed for the storage of ton containers at the UMDA and NAAP site warehouses. For the UMDA site, there were 17 release sequences with frequencies above 10^{-10}/yr. Table 7-3 lists these sequences along with the information pertinent to the release calculations. For sequences in which the burning or agent spilled from breached munitions is the only release mode, a range of release is given corresponding to the range of containers breached (1 to 5 or 2 to 10). For sequences in which the nonsuppressed fire ignites the entire warehouse inventory, the number of breached containers is unimportant.

Table 7-4 presents the corresponding release results for ton containers stored at the NAAP site. Only five sequences are important since there is only one warehouse at the site. The maximum masses of agent VX released from this site are seven times lower than maximum mass releases of agent HD from UMDA.

In the event tree for spray tanks stored at the TEAD site, there were six significant sequences as given in Table 7-5. Since no spray tanks are mechanically breached, the only consequence variable is whether the unsuppressed fire is not suppressed in one or both warehouses. The releases upon burning of the entire inventory at one or both warehouses are given in Table 7-5. They are 8 to 16 times lower than the maximum release of the same agent (VX) from the NAAP site.

7.2.2. Uncertainties

No uncertainty analysis was performed for the agent release analysis. The releases reported are treated as conservative estimates, rather than central estimates, since they are based on assumptions which

TABLE 7-3
AGENT HD RELEASES FROM TON CONTAINERS STORED IN
UMDA WAREHOUSES DURING EARTHQUAKES[a]

Sequence ID	No. of Munitions Damaged	Spilled Munition Agent Burns	No. Warehouses In Which Entire Inventory Burns	Release To Atmopshere (lb)
SLKHF281	0	--	1	2.7×10^5
SLKHF282	0	--	2	5.4×10^5
SLKHC283	1-5	No	0	ϵ[b]
SLKHF284	1-5	Yes	1	2.7×10^5
SLKHF285	1-5	No	1	2.7×10^5
SLKHF286	1-5	Yes	2	5.4×10^5
SLKHC287	2-10	No	0	ϵ
SLKHF288	2-10	Yes	1	2.7×10^5
SLKHF289	2-10	Yes	2	5.4×10^5
SLKHC2810	1-5	No	0	ϵ
SLKHF2811	1-5	Yes	1	2.7×10^5
SLKHF2812	1-5	Yes	2	5.4×10^5
SLKHC2813	2-10	No	0	ϵ
SLKHF2814	2-10	Yes	1	2.7×10^5
SLKHF2815	2-10	Yes	2	5.4×10^5
SLKHC2816	2-10	No	0	ϵ
SLKHF2817	2-10	Yes	2	5.4×10^5

[a] Agent inventory = 5.4×10^6 lb per warehouse, assuming warehouse is full.

[b] ϵ = negligible (below 14 lb).

TABLE 7-4
AGENT VX RELEASES FROM NAAP WAREHOUSE TON CONTAINERS DURING EARTHQUAKES[a]

Sequence ID	No. of Munitions Damaged	Spilled Munition Agent Burns	Entire Warehouse Inventory Burns	Release To Atmosphere (lb)
SLKVF261	0	--	Yes	7.5×10^4
SLKVC262	1-5	No	No	ϵ[b]
SLKVF263	1-5	Yes	Yes	7.5×10^4
SLKVC264	1-5	No	No	ϵ
SLKVF265	1-5	Yes	Yes	7.5×10^4

[a] Warehouse inventory = 3×10^6 lb of VX, assuming warehouse is full.

[b] ϵ = negligible (below 0.3 lb).

TABLE 7-5
AGENT VX RELEASE FROM SPRAY TANKS STORED AT TEAD WAREHOUSES DURING EARTHQUAKES[a]

Sequence ID	No. Warehouses In Which Entire Inventory Burns	Release To Atmosphere (lb)
SLSVF271	1	4.5×10^3
SLSVF272	2	9.0×10^3
SLSVF273	1	4.5×10^3
SLSVF274	2	9.0×10^3
SLSVF275	1	4.5×10^3
SLSVF276	2	9.0×10^3

[a] Agent inventory = 1.79×10^5 lb of VX, assuming warehouse is full.

are often conservative. Examples are: (1) use of early thresholds of munition failure relative to the data (Appendix F), (2) worst-case number of adjacent munition ruptures for a munition detonation in a pallet, (3) use of maximum rather than average inventories, and (4) upper bound fire release factors, relative to the data.

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8. RESULTS

The analysis of the potential for agent release to the atmosphere from accident scenarios related to the continued storage alternative included storage and handling activities. This section discusses some of the accident probability and agent release results associated with these activities.

The results of the analysis of the various activities encompassing the continued storage alternative cannot be presented in the same units, i.e., annual frequencies, because of the possible divulgence of classified information. This is only possible for some storage accident scenarios. For accident scenarios related to the handling activities, the unclassified portion of the probabilistic analysis is given in terms of frequency of accidents per pallet of munitions (or as a container of munitions).

The evaluation of the actual risk to the public and environment requires agent dispersion calculations which are not in the scope of the study reported here. Despite this limitation, the results discussed herein still provide useful insights on the contributions of the various disposal activities to the risk of an agent release. These insights are discussed below.

8.1. ACCIDENT SCENARIOS DURING STORAGE

The continued storage alternative requires some storage of munitions in their existing location.

8.1.1. Internal Events

There were no significant internal event initiators of accidents during storage. Per unit operation, forklift drop accidents occur more frequently than forklift tine punctures. Also, the use of a lifting beam instead of a tine leads to an order of magnitude decrease in drop frequency.

8.1.2. External Events

These events involve accidents caused by natural phenomena or human activity affecting munitions in storage igloos, open storage areas, holding areas, or warehouses. If these are assumed to be full of munitions, the agent inventories range up to 100, 200, 1000, and 2000 tons, respectively, for storage igloos, holding areas, open areas, and warehouses. The most frequent external accidents having significant release involve mild intensity earthquakes or small airplane crushes (order depending on site). Amounts of available agent inventories released in these events are on the order of fractions of one percent or less (munition punctures, drops, etc.).

The largest releases occur for a large aircraft crash, a meteorite strike, or a severe earthquake, especially when a warehouse (at NAAP, TEAD, or UMDA) is involved. These can result in up to 10 percent of the agent inventory released for scenarios involving a fire which has the potential (duration) for destroying the entire inventory of an igloo or warehouse. The munitions stored in warehouses contain only VX or mustard which have much slower evaporation rates than GB and hence are not easily dispersed into the atmosphere. Thus, warehouse scenarios involving only spills are not significant risk contributors. The warehouse at UMDA has the potential for the largest release. Meteorite strike-initiated sequence median frequencies are one to two orders of magnitude lower than the aircraft crash-induced sequence frequencies. As expected, munitions stored outdoors are generally more susceptible to large aircraft crashes than those stored in warehouses or igloos, but releases are lower. Both APG and PBA have ton containers stored outdoors, and the aircraft crash probabilities at these sites are somewhat higher than at the other sites. Igloos appear to provide only minimal protection from direct crashes of large planes, but releases are an order of magnitude lower. The releases are more severe if burstered munitions are involved.

8.2. ACCIDENT SCENARIOS DURING HANDLING

Included in the handling analysis are single munition or pallet movements by hand, forklift, or other equipment.

The results indicate that dropped munitions, whether in palletized form or not, occur more frequently than either forklift tine puncture or forklift collision accidents. In fact, the frequency of forklift collision accidents which lead to the munitions falling off the forklift is an order of magnitude lower than the drop accidents. Furthermore, the type of clothing an operator is wearing while handling these munitions influence the drop frequency value. An operator wearing Level A clothing is more likely to commit an error that would cause the munition to be dropped than when he is wearing more comfortable clothing.

For bare munitions, the rockets seem to be the most prone to punctures from drops or forklift tine accidents.

Bulk items that are punctured lead to larger releases than other munitions such as projectiles or rockets. Bombs are of concern because they contain GB which evaporates more readily than the other agent types. The agent vapor releases range up to 170 lb (thermal failure of all munitions in a pallet).

Handling accidents which lead to significant agent releases (in particular, agent GB) are dominant risk contributors because of the relatively higher annual frequency values. Of course depending on the actual munition inventory, the value of annual frequency may either increase or decrease when converted to the more meaningful per stockpile basis.

8.3. UNCERTAINTIES IN THE ANALYSIS

In assessing the risks associated with the CSDP alternatives, every effort was made to perform best-estimate analyses, i.e., "realistic" evaluation and quantification of the accident sequence frequencies and associated agent releases. The use of pessimistic or conservative modeling techniques or data for quantification violates the intent of the probabilistic nature of the study. Realistic modeling and quantification permits a balanced evaluation of risk contributors and comparison of alternatives. However, for realistic or best-estimate calculations, the obvious concern is the accuracy of the results. Uncertainty analysis addresses this concern.

8.3.1. Sources of Uncertainty

Since the event sequences discussed in Section S.3 have not actually occurred, it is difficult to establish the frequency of the sequence and associated consequences with great precision. For this reason, many parameters in a risk assessment are treated as probabilistically distributed parameters, so that the computation of sequence frequencies and resulting consequences can involve the probabilistic combination of distributions.

There are three general types of uncertainty associated with the evaluations reported in this document: (1) modeling, (2) data, and (3) completeness.

There exist basic uncertainties regarding the ability of the various models to represent the actual conditions associated with the sequence of events for the accident scenarios that can occur in the storage and disposal activities. The ability to represent actual phenomena with analytical models is always a potential concern. The use of fundamental models such as fault trees and event trees is sometimes simplistic because most events depicted in these models are treated as leading to one of two binary states: success or failure (i.e., partial successes or failures are ignored). Model uncertainties are difficult to quantify and are addressed in this study by legitimate efforts of the analysts to make the models as realistic as possible. Where such realism could not be achieved, conservative approaches were taken.

No uncertainty from oversights, errors, or omission from the models used (e.g., event trees and fault trees) is included in the uncertainty analysis results. Including these uncertainties is beyond the state-of-the-art of present day uncertainty analysis.

The uncertainties in the assignment of event probabilities (e.g., component failure rates and initiating event frequencies) are of two types: intrinsic variability and lack of knowledge. An example of intrinsic variability is that where the available experience data is for a population of similar components in similar environments, but not all the components exhibit the same reliability. Intrinsic variations can be caused, for example, by different manufacturers, maintenance practices, or operating conditions. A second example of intrinsic variability is that related to the effects of long-term storage on the condition of the munitions as compared to their original configuration. Lack of knowledge uncertainty is associated with cases where the model parameter is not a random or fluctuating variable, but the analyst simply does not know what the value of the parameter should be. Both of these data uncertainty types are encountered in this study.

8.3.2. Uncertainties

The sequence frequency results discussed in this report are presented in terms of a median value and a range factor of a probability distribution representing the frequency of interest. The range factor represents the ratio of the 95th percentile value of frequency to the 50th percentile (i.e., median) value of frequency. The uncertainty in the sequence frequency is determined using the STADIC-2 program

(Ref. 8-1) to propagate the uncertainties associated with each of the events in the fault trees or event trees through to the end result. Some scenarios, such as those associated with tornado missiles and low-impact detonations have rather large uncertainties. The difficulty with tornado-generated missiles lies with the difficulty in accurately modeling the probability that the missile will be in the proper orientation to penetrate the munition and in predicting the number of missiles per square foot of wind. The difficulty with the low-impact detonations lies with the sparse amount of data available and its applicability to the scenarios of interest. In general, uncertainties tend to be large when the amount of applicable data is small and vice versa.

8.4. REFERENCES

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APPENDIX A
REFERENCE LIST OF ACCIDENT SEQUENCES

A.1. REFERENCE LIST OF ACCIDENT SEQUENCES

A reference list of accident sequences is presented here. Accident sequences related to storage are presented first followed by handling activities related to surviellance and maintenance. The sequences can be identified by the coding scheme presented in Section 4 of this document. Following the sequence ID, a brief description of the accident is given along with an indication as to whether or not the sequence was considered for further analysis. The bases for scenario screening are provided in the logic model section, Section 4, of the main body of this report.

ACCIDENT SEQUENCES FOR LONG-TERM STORAGE

Sequence ID	Sequence Description	Considered for Further Analysis
SL1	Munition develops a leak during the in-between inspection period.	Yes
SL2	Munition punctured by forklift tine during leaker-handling activities.	Yes
SL3	Spontaneous ignition of rocket during storage (not analyzed for lack of quantitative data).	No
SL4	Large aircraft direct crash onto storage area; fire not contained in 30 min. (Note: Assume detonation occurs if burstered munitions hit; fire involving burstered munitions not contained at all.)	Yes
SL5	Large aircraft indirect crash onto storage area; fire not contained in 30 min. (See note in SL4.)	Yes
SL6	Tornado-generated missiles strike the storage magazine, warehouse, or open storage area; munitions breached (no detonation).	Yes
SL7	Severe earthquake breaches the munitions in storage igloos; no detonations.	Yes
SL8	Meteorite strikes the storage area; fire occurs; munitions breached (if burstered, detonation also occurs).	Yes
SL9	Munition dropped during leaker isolation operation; munition punctured.	Yes
SL10	Storage igloo or warehouse fire from internal sources.	No
SL11	Munitions are dropped due to pallet degradation.	No
SL12	Liquid petroleum gas (LPG) infiltrates igloo/building.	No
SL13	Flammable liquids stored in nearby facilities explode; fire propagates to munition warehouse (applies to NAAP).	No

ACCIDENT SEQUENCES FOR LONG-TERM STORAGE (Continued)

Sequence ID	Sequence Description	Considered for Further Analysis
SL14	Tornado-induced building collapse leads to breaching/detonation of munitions.	No
SL15	Small aircraft direct crash onto warehouse or open storage yard; fire occurs; not contained in 30 min.	Yes
SL16	Large aircraft direct crash; no fire; detonation (if burstered).	Yes
SL17	Large aircraft direct crash; fire contained within 30 min (applies to nonburstered munitions only).	Yes
SL18	Small aircraft direct crash onto warehouse or open storage yard; no fire.	Yes
SL19	Small aircraft direct crash onto warehouse or open storage yard; fire contained in 30 min.	Yes
SL20	Large aircraft indirect crash onto storage area; no fire.	Yes
SL21	Large aircraft indirect crash onto storage area; fire contained in 30 min.	Yes
SL22	Severe earthquake leads to munition detonation.	Yes
SL23	Tornado-generated missiles strike the storage igloo and leads to munition detonation.	Yes
SL24	Lightning strikes ton containers stored outdoors.	Yes
SL25	Munition dropped during leaker isolation; munition detonates.	Yes
SL261	Earthquake occurs; NAAP warehouse is intact; no ton containers damaged; fire occurs.	Yes
SL262	Earthquake occurs; NAAP warehouse is intact; ton container damaged; no fire.	Yes
S1263	Earthquake occurs; NAAP warehouse is intact; ton container damaged; fire occurs.	Yes

ACCIDENT SEQUENCES FOR LONG-TERM STORAGE (Continued)

Sequence ID	Sequence Description	Considered for Further Analysis
SL264	Earthquake occurs; NAAP warehouse is damaged; ton containers damaged; no fire.	Yes
SL265	Earthquake occurs; NAAP warehouse is damaged; ton containers damaged; fire occurs.	Yes
S1271	Earthquake occurs; TEAD warehouses intact; munitions intact; fire occurs at one warehouse.	Yes
SL272	Earthquake occurs; TEAD warehouses intact; munitions intact; fire occurs at two warehouses.	Yes
SL273	Earthquake occurs; one TEAD warehouse is damaged; munitions intact; fire occurs at one warehouse.	Yes
SL274	Earthquake occurs; one TEAD warehouse is damaged; munitions intact; fire occurs at two warehouses.	Yes
SL275	Earthquake occurs; two TEAD warehouses damaged; munitions intact; fire occurs at one warehouse.	Yes
SL276	Earthquake occurs; two TEAD warehouses damaged; munitions intact; fire occurs at two warehouses.	Yes
SL281	Earthquake occurs; UMDA warehouses intact; munitions intact; fire occurs at one warehouse.	Yes
SL282	Earthquake occurs; UMDA warehouses intact; munitions intact; fire occurs at two warehouses.	Yes
SL283	Earthquake occurs; UMDA warehouses intact; munitions in one warehouse damaged; no fire occurs.	Yes
SL284	Earthquake occurs; UMDA warehouses intact; munitions in one warehouse damaged; fire occurs at warehouse with damaged munitions.	Yes
SL285	Earthquake occurs; UMDA warehouses intact; munitions in one warehouse damaged; fire occurs at warehouse with undamaged munitions.	Yes
SL286	Earthquake occurs; UMDA warehouses intact; munitions in one warehouse damaged; fire occurs at two warehouses.	Yes

ACCIDENT SEQUENCES FOR LONG-TERM STORAGE (Continued)

Sequence ID	Sequence Description	Considered for Further Analysis
SL287	Earthquake occurs; UMDA warehouses intact; munitions in two warehouses damaged; no fire occurs.	Yes
SL288	Earthquake occurs; UMDA warehouses intact; munitions in two warehouses damaged; fire occurs at warehouse with damaged munitions.	Yes
SL289	Earthquake occurs; UMDA warehouses intact; munitions in two warehouses damaged; fire occurs at two warehouses.	Yes
SL2810	Earthquake occurs; one UMDA warehouse damaged; munitions in one warehouse damaged; no fire occurs.	Yes
SL2811	Earthquake occurs; one UMDA warehouse damaged; munitions in one warehouse damaged; fire occurs at warehouse with damaged munitions.	Yes
SL2812	Earthquake occurs; one UMDA warehouse damaged; munitions in one warehouse damaged; fire occurs at two warehouses.	Yes
SL2813	Earthquake occurs; one UMDA warehouse damaged; munitions in two warehouses damaged; no fire occurs.	Yes
SL2814	Earthquake occurs; one UMDA warehouse damaged; munitions in two warehouses damaged; fire occurs warehouse with damaged munitions.	Yes
SL2815	Earthquake occurs; one UMDA warehouse damaged; munitions in two warehouses damaged; fire occurs at two warehouses.	Yes
SL2816	Earthquake occurs; two UMDA warehouses damaged; munitions in two warehouses damaged; no fire occurs.	Yes
SL2817	Earthquake occurs; two UMDA warehouses damaged; munitions in two warehouses damaged; fire occurs at both warehouses.	Yes

ACCIDENT SEQUENCES FOR SURVEILLANCE AND MAINTENANCE HANDLING ACTIVITIES

Sequence ID	Sequence Description	Considered for Further Analysis
SH1	Drop of pallet or container in storage area or maintenance facility; munition punctured.	Yes
SH2	Forklift collision with short duration fire.	Yes
SH3	Forklift tine puncture	Yes
SH4	Forklift collision without fire.	Yes
SH5	Drop of munition leads to detonation.	Yes
SH6	Collision accident leads to detonation.	Yes
SH7	Collision accident with prolonged fire.	Yes
SH8	Munition pallet dropped during pallet inspection.	Yes
SH9	Forklift tine puncture during pallet inspection.	Yes
SH10	Forklift collision during pallet inspection.	Yes
SH11	Munition pallet dropped during pallet inspection; detonation occurs.	Yes
SH12	Forklift collision; detonation occurs.	Yes

APPENDIX B
(Deleted)

APPENDIX C
STRUCTURAL ANALYSIS

C.1. STRUCTURAL ANALYSIS

This appendix summarizes the structural analysis methodology used to determine failure thresholds and probabilities for munitions and structures. Supporting calculation for the results used in this study can be found in Ref. C-1.

C.1.1. PUNCTURE

This section addresses two types of munition puncture: (1) puncture due to dropping a munition; and (2) forklift puncture.

C.1.1.2. Puncture Due to Drop

The probability P_F of a munition puncturing on impact with a probe depends on the type of munition, the number of probes to which a dropped munition is exposed, and the geometry of the probe. This probability is computed from the following:

$$P_F = P_D \times PLL \times PD \times A_s \quad ,$$

where P_D = probe density (number of probes per square foot of surface area),

PLL = an admissible probability value for probe length to diameter ratio,

PD = an admissible probability value for probe diameter,

A_s = the area of the munition in square feet which is subject to penetration by the probe.

The number of probes per square foot of surface area (P_B) is based on engineering judgment. It is assumed that the igloo is clean and that objects that could be potential probes are not likely to be left in the igloo. Therefore, one probe per igloo (i.e., one probe per 2160 ft^2) was assumed for igloo storage. For all other storage areas, a probe density of one per 1000 ft^2 was assumed. In the general working area, loading docks, etc., it is assumed that the potential for probes will be much more likely than in an igloo. Probes such as posts, tools, rocks, or chunks of steel are possible; therefore, one probe per 100 ft^2 is assumed for the general working area. In the UPA during an earthquake, it is assumed that the earthquake could generate additional probes by causing objects to fall onto the floor; therefore, one probe per 50 ft^2 is assumed for the UPA during an earthquake.

The PLL term in the above expression represents the probability that the probe has a length-to-diameter ratio (L/D) which is less than that which would cause buckling failure of the probe without penetration of the dropped munition but greater than that corresponding to a probe length which is insufficient to penetrate the munition. Probe dimensions (diameter and L/D) were treated statistically and the minimum probe length for penetration was calculated for each munition.

The PD term in the above expression represents the probability that the diameter of the probe is less than or equal to the maximum that could penetrate the munition but greater than a minimum diameter corresponding to the compressive strength of the probe. The maximum diameter of the probes which could penetrate through the munition wall is determined from

$$D_u = \frac{(W \times H)^{0.667}}{672\ t} \quad ,$$

where D_u = maximum probe diameter (in.),

W = weight of munition/pallet (lb),

H = drop height (ft),

t = munition thickness (in.).

These expressions are taken from Ref. C-2.

The munition area vulnerable to probe penetration (A_s) was determined assuming a maximum probe length of 2 in. This term was calculated for each munition/pallet configuration of interest and reflects the number of munitions involved in each handling operation. Thus, if more than one munition were being handled, the vulnerable area of each munition was multiplied by the actual number of munitions involved in the handling event.

C.1.1.2. Forklift Tine Puncture

For forklift tine puncture, the munitions are at rest and the probe (the forklift tine) is the moving object. This makes calculating the munition vulnerability simpler since the mass of the moving object (the forklift) and the shape of the probe (the tine) are the same for all munitions. The only variable is the munition thickness. Since the puncture energy is proportional to the thickness of the munition, the relative puncture resistance of the munitions is simply the ratio of the thicknesses.

The probability P of a forklift tine puncture of the munitions was assumed to be governed by

$$P = P_1 * P_2 * N \quad ,$$

where P_1 = the probability that a munition is struck by a forklift tine per pallet operation,

P_2 = the probability that the munition is punctured given that the forklift tine strikes the munition,

N = number of handling operations.

The critical puncture velocity V_c (in ft/s) was determined from

$$V_c = \frac{64}{W} (672\ Dt)^{3/2} \quad ,$$

where W = weight of the forklift (lb),

D = equivalent diameter of the forklift tine (in.),

t = munition wall thickness (in.).

C.1.2. WIND-GENERATED MISSILES

The probability of a wind-generated missile rupturing a munition is the product of two probabilities: (1) the probability of having a wind of sufficient velocity to generate a missile that can rupture a munition and (2) the probability that the missile hits the munitions in an orientation that will rupture the munition.

C.1.2.1. Required Wind Velocity

The wind velocity required to generate a missile that can penetrate a munition is computed as follows:

1. The missile velocity required to penetrate the munition is computed using the equation (Ref. C-2):

$$V_m = 0.682 \quad \frac{64}{W} \, (672 \, Dt)^{3/2} \quad ,$$

where V_m = the penetration velocity (mph),
W = the weight of the missile (lb),
D = the equivalent missile diameter (in.),
t = the wall thickness of the munition (in.).

Each munition was evaluated for two critical missiles: a 10-ft section of 3-in. pipe and a 13.5-in. diameter utility pole. In addition to penetration, the utility pole was evaluated to determine the velocity required to crush the munition.

2. The missile velocity required to penetrate the storage structure was also computed using the following equation (Ref. C-2).

For concrete structures:

$$V_s = 1000 \left(\frac{f_c \, T \, D^{1.8}}{427 \, W} \right)^{0.75} ,$$

where T = thickness of concrete element to be just perforated (in.),

W = weight of missile (lb),

D = diameter of missile (in.),

V_s = striking velocity of missile (fps),

f_c = compressive strength of concrete (psi).

For steel structures:

$$V_s = 0.682 \; \frac{64}{W} \, (672 \; DT)^{3/2} .$$

3. The missile velocity required to penetrate both the munition and structure is computed using the following equation which is based on summing the energies required to penetrate the munition and structure separately:

$$V = \sqrt{V_m^2 + V_s^2} ,$$

where V_m = velocity required to penetrate the munition,

V_s = velocity required to penetrate the structure.

4. The probability of the required wind occurring was based on functional data for each site.

C.1.2.2. Probability of Hitting and Rupturing the Munition

Given a sufficient wind, the probability that a missile hits and ruptures a munition was computed from:

$$P = P_d \, P_o \, D \, A \quad ,$$

where P_d = probability that the direction of missile travel is nearly perpendicular to the target,

P_o = probability that the missile is oriented to penetrate (i.e., not tumbling or going sideways),

D = number of missiles per unit area,

A = area of target.

Values for P_d, P_o, and D are difficult to evaluate and are not available from the literature. Consequently, the values used for the analysis were computed based on engineering judgment. These values were selected to give a "best estimate" of the overall probability. The following is a discussion of these assumptions.

The missile velocity must be nearly perpendicular to the wall of a structure or munition in order for the missile to penetrate. The further the missile strikes from an angle which is perpendicular, the less likely that the missile will penetrate. As the angle deviates from the perpendicular, the effective thickness of munition increases proportionally to the reciprocal of the cosine of the angle (where the angle is measured from the perpendicular); thus, a higher missile velocity (which has a lower probability of occurring) is required for penetration. In addition, the missile is more likely to ricochet at higher angles. Based on engineering judgment, it is estimated that if the missile velocity is more than 30 deg off from perpendicular, the missile will not penetrate. This yields a value of 0.17 for P_d.

The missile velocity must be aligned along the missile axis in order for the missile to penetrate. In other words, the missile must move like an arrow rather than tumbling or going sideways. Of the two missiles analyzed, it was found that it is more important that the pipe be aligned properly than the utility pole because of the larger impact area of the utility pole. For this reason, it was assumed that the velocity must be aligned within 5 deg of the axis of the pipe and within 10 deg of the axis of the utility pole. These assumptions resulted in values for P_o of 0.004 for the pipe and 0.015 for the utility pole.

The path of the tornado is generally from 1/8 to 3/4 of a mile wide (Ref. C-3). For this analysis, it was assumed that the tornado is 1/2 mile wide and that it carries one utility pole and 10 iron pipes. It was further assumed that the pipes are evenly distributed to a height of 50 ft and the utility pole at a height of 20 ft (Ref. C-4 indicates the maximum heights for pipes is 100 ft and for utility poles is 50 ft which indicates that our assumption is conservative). Therefore, the number of missiles per square foot of wind (D) is 7.6×10^{-5} for pipes and 1.9×10^{-5} for utility poles.

The target area is different for each scenario and depends on the number of munitions involved and the storage configuration (see Ref. C-1).

The product of P_d, P_o, and D is approximately 5.0×10^{-8} for both the pipes and utility pole.

C.1.3. EARTHQUAKE AND WIND FAILURE OF UBC DESIGNED STRUCTURES

C.1.3.1. Strength Factor of Safety

The Uniform Building Code (UBC) ensures that structures are designed with a factor of safety. This factor of safety varies depending on the type of structure, materials used and components selected. For earthquake and wind loads, this factor of safety ranges from 1.3 to 1.6 for concrete structures designed to ultimate design strength principals and from 2.6 to 3.0 for concrete and steel structures designed to working stress methods. For the risk analyses in this report, it is assumed that the factor of safety will be 1.3 for concrete structures (since the CONUS structures are being designed to ultimate strength) and 2.6 for the steel structures.

C.1.3.2. Wind Loads

For UBC-designed concrete structures such as the MDB, wind does not govern the design of the main structural components. The MDB is a rigid concrete moment resisting framed and shear wall structure and will fail under seismic conditions only. For the steel structures such as the bulk agent warehouses, the wind governs the design in most cases. Wind loads will fail the walls of the structure before the structure will collapse. Since the stresses in a structure due to winds are proportional to the square of the wind velocity, a wind velocity which is 1.6 (square root of the 2.6 factor of safety on strength) times greater than the design wind load can be expected to fail the walls of the steel structure.

C.1.3.3. Earthquake Loads

The Applied Technology Council (ATC), which is associated with the SEAOC, presents a set of curves that can be used to estimate the probability of an earthquake, which exceeds a specific g-level, occurring anywhere in the U.S. (Ref. C-5). These curves are shown in Section 4.2. Each curve represents a seismic map area which is similar to the seismic zones used by the UBC. The ATC divided the country into seven seismic map areas (1-7). The UBC uses five seismic zones (0-4). Reference C-5 contains maps showing the seismic map areas. These maps color code the seismic map areas, and, consequently, have not been reproduced for this report since a black and white reproduction would not be helpful. The maps show that APG, ANAD, LBAD, PBA, UMDA, and PUDA are in seismic map area 2; NAAP is in seismic map area 3; and TEAD is in seismic map area 5.

Section 4.2 presents the seismic risk curves for seismic map areas 2, 3, 5, and 7.

The earthquake g-level that will fail a structure depends on four principal factors: (1) the design g-level, (2) the strength factor of safety, (3) the dynamic amplification in the structure, and (4) the ductility of the structure. The dynamic amplification factor reduces the factor of safety, and the ductility increases the factor of safety. The dynamic amplification factor has been conservatively estimated at 2.3 based on a referenced analysis (Ref. C-6). Ductility factors are estimated to be in the range of 2.5 to 3.5 for concrete structures with shear walls and from 3.5 to 5.0 for steel structures. For this analysis, 2.5 was used for concrete walls and 3.5 was used for steel-walled structures. Based on these factors, a UBC structure with concrete walls was assumed to fail at an earthquake g-level that is approximately 1.4 times the design g-level, and a UBC structure with steel walls was assumed to fail at a g-level that is approximately 4.0 times greater than the design g-level.

For UBC designed structures with concrete walls in Seismic Zone 3 (design g-level of 0.14), the expected failure g-level is 0.4 g. Due to the uncertainty of the analysis, there is a probability that the structure will survive larger earthquakes or will fail during smaller earthquakes. Consequently, the following probabilities of failure have been assumed:

1. A 0.3-g earthquake has a 0.1 probability of producing failure.
2. A 0.4-g earthquake has a 0.5 probability of producing failure.
3. A 0.5-g earthquake has a 0.9 probability of producing failure.
4. A 0.6-g earthquake has a 1.0 probability of producing failure.

The failure g-levels for Seismic Zone 2 are half of the g-levels for Seismic Zone 3 since the design g-level for Seismic Zone 2 (0.07 g) is half the design g-level for Seismic Zone 3 (0.14 g).

For UBC designed structures with steel walls in Seismic Zone 2 (the warehouses at NAAP and UMDA), the following probabilities of failure have been assumed:

1. A 0.2-g earthquake has a 0.1 probability of producing failure.
2. A 0.3-g earthquake has a 0.5 probability of producing failure.
3. A 0.4-g earthquake has a 0.9 probability of producing failure.
4. A 0.5-g earthquake has a 1.0 probability of producing failure.

C.1.4. EARTHQUAKE FAILURE OF NRC-DESIGNED STRUCTURES

The TOX cubicle, tank, and piping system will be designed to Nuclear Regulatory Commission (NRC) standards for nuclear power plants. In summary, this will involve the following:

1. Seismic experts will determine the "maximum credible earthquake" that can occur at TEAD based on the seismic history of the area and the proximity of earthquake faults. This "maximum credible earthquake" will be selected as the safe shutdown earthquake (SSE) to be used as the design earthquake for the TOX at all eight sites.

2. The TOX will be analyzed for the SSE using finite-element time-history computer programs.

3. The TOX will be constructed to NRC standards.

Since the design g-level has not yet been determined, an SSE g-level had to be assumed with the intent to ensure that the TOX will withstand relatively high g-forces. For this risk analysis, it was conservatively assumed that the TOX will be designed for a 1-g SSE.

Since the TOX will be designed for no failures in the event of a SSE, an earthquake larger than the SSE will be required to produce a failure. Since the NRC seismic design requirements are quite different from the UBC seismic requirements, the methodology used to determine failure g-levels for the UBC structures does not apply to NRC-designed structures. Based on GA's experience in seismic design of nuclear power plants, it was estimated that an earthquake which is twice the SSE will have a 0.5 probability of either rupturing the TOX tank/piping system or breaching the TOX wall. There is a possibility that the TOX will survive larger earthquakes or that a smaller earthquake will cause a failure. Consequently, the following probabilities are selected for the rupture of the TOX storage tank and for the breaching of the TOX walls:

1. A 1.8-g earthquake has a 0.1 probability of producing failure.
2. A 2.0-g earthquake has a 0.5 probability of producing failure.
3. A 3.0-g earthquake has a 0.9 probability of producing failure.
4. A 4.0-g earthquake has an ~1.0 probability of producing failure.

C.1.5. METEORITES

The probability of a meteorite penetrating a munition can be estimated from:

$$P = F\ (f_i + f_s)\ A\ S \quad ,$$

where F = frequency of meteorite strikes per square foot of area,

f_i = fraction of the striking meteorites which are iron meteorites and can penetrate the target,

f_s = fraction of the striking meteorites which are stone meteorites and can penetrate the target,

A = area of target,

S = fraction of the target area which must be impacted to rupture a munition or bulk agent container (spacing factor).

The frequency of meteorite strikes for meteorites 1.0 lb or greater is $0.4 \times 10^{-13}/ft^2$ (Ref. C-7). For small meteorites (a ton or less), stone meteorites are approximately 10 times more common than iron meteorites (Ref. C-8). However, iron meteorites are more dense and tend to have higher impact velocities, and consequently, represent a significant portion of the total meteorites that can rupture munitions. The size distribution of both iron and stone meteorites striking the earth surface was estimated from the data presented in Refs. C-7 and C-8.

The size of the meteorite required to penetrate a munition or munition and structure was computed using the equations presented in Ref. C-2. The impact velocity was computed based on the data presented in Ref. C-8, which gives impact velocities for a series of large meteorites. These data were plotted and extrapolated to estimate the velocities for the smaller meteorites. For the smallest stone meteorites, the extrapolation yields impact velocities which were less than their terminal velocities. In these cases the terminal velocities are used.

C.1.6. AIRCRAFT CRASH

The probabilities used in the analysis of crashes involving aircraft takeoffs and landings were obtained by modifying Table C-1, which was taken from Ref. C-9. The following modifications were made to this table:

1. U.S. air carrier (commercial) crash probabilities between 5 and 8 miles from the end of the runway were increased from 0.0 to 0.14×10^{-8} which is equal to the probability for crashes between 8 and 9 miles from the end of the runway.

2. The probabilities for USN/USMC were averaged with the probabilities for USAF to obtain probabilities for military aircraft in general.

3. The probabilities for crashes of military aircraft at distances which are 5 to 10 miles from the runway were assumed to be the same as for U.S. commercial air carriers.

4. The general aviation probabilities for crashes which are 5 to 10 miles from the end of the runway are assumed to be five times greater than U.S. air carrier probabilities.

5. Helicopter crash probabilities were assumed to be twice the probabilities for general aviation.

Tables C-2 through C-17 summarize the input data that were used to calculate the annual probabilities of both small and large aircraft crashes at each of the eight sites. The effective areas of the crash sites are summarized in Table C-18.

TABLE C-1
AIRCRAFT CRASH PROBABILITIES NEAR AIRPORTS[a]

Distance From End of Runway (miles)	Probability (x 10^8 of a Fatal Crash per Square Mile per Aircarft Movement[a]			
	U.S. Air Carrier	General Aviation	USN/USMC	USAF
0-1	16.7	84.0	8.3	5.7
1-2	4.0	15.0	1.1	2.3
2-3	0.96	6.2	0.33	1.1
3-4	0.68	3.8	0.31	0.42
4-5	0.27	1.2	0.20	0.40
5-6	0	NA	NA	NA
6-7	0	NA	NA	NA
7-8	0	NA	NA	NA
9-9	0.14	NA	NA	NA
9-10	0.12	NA	NA	NA

[a]Reference C-9.

TABLE C-2
CRASH OF A LARGE AIRPLANE AT APG

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
NONE											0

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
PHILLIPS AAF	0	1.2e+01	1.4e-09	1.7e-08	1.0e+02	1.4e-09	1.5e-07	5.2e+01	7.0e-09	3.6e-07	5.3e-07
WEIDE AAF	1	0.0e+00	1.7e-07	0.0e+00	0.0e+00	7.0e-08	0.0e+00	0.0e+00	8.4e-07	0.0e+00	0.0e+00
										TOTAL	5.3e-07

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-3
CRASH OF A SMALL AIRPLANE AT APG

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
-	6	1.2e+01	4.8e-10	9.6e-10	2.4e+01	2.0e-09	9.6e-09	1.2e+01	2.0e-09	4.8e-09	1.5e-08

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
PHILLIPS AAF	8	1.2e+01	1.4e-08	1.7e-08	2.4e+01	1.4e-09	3.4e-08	2.4e+01	7.0e-09	1.7e-07	2.2e-07
WEIDE AAF	1	0.0e+00	1.7e-07	0.0e+00	4.0e+02	7.0e-08	2.8e-06	1.3e+03	8.4e-07	1.1e-03	1.1e-03
										TOTAL	1.1e-03

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-4
.RASH OF A LARGE AIRPLANE AT ANAD

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
J14-52	8	1.0e+04	4.0e-10	5.0e-09	5.0e+03	2.0e-09	1.3e-08	5.0e+03	2.0e-09	1.3e-08	3.0e-08
V18	12	4.0e+03	4.0e-10	1.3e-09	2.4e+03	2.0e-09	4.0e-09	4.0e+03	2.0e-09	6.7e-09	1.2e-08
IR69	4	0.0e+00	4.0e-10	0.0e+00	7.3e+03	2.0e-09	3.7e-08	0.0e+00	2.0e-09	0.0e+00	3.7e-08

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
NONE											0.0e+00
										TOTAL	7.9e-08

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-5
CRASH OF A SMALL AIRPLANE AT ANAD

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
J14-62	8	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00
V18	12	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	7.0e+04	2.0e-09	1.2e-06	1.2e-06
IR60	4	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
NONE											0.0e+00
										TOTAL	1.2e-06

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-6
CRASH OF A LARGE AIRPLANE AT LBAD

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
J8	8	6.0e+03	4.0e-10	2.6e-07	2.6e+03	2.0e-09	6.3e-07	2.6e+03	2.0e-09	6.3e-07	1.5e-06
J43	12	6.0e+03	4.0e-10	1.7e-07	2.6e+03	2.0e-09	4.2e-07	2.6e+03	2.0e-09	4.2e-07	1.0e-06
BOMBING RUN	4	0.0e+00	4.0e-10	0.0e+00	4.0e+03	2.0e-09	2.0e-06	0.0e+00	2.0e-09	0.0e+00	2.0e-06

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
NONE											0.0e+00
										TOTAL	4.5e-06

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-7

CRASH OF A SMALL AIRPLANE AT LBAD

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
J6	8	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00
J43	12	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00
BOMBING RUN	4	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00
-	8	4.0e+02	4.0e-10	2.0e-08	2.4e+02	2.3e-09	6.0e-08	4.0e+02	2.0e-09	1.0e-07	1.0e-07

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
NONE											0.0e+00
										TOTAL	1.0e-07

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-8
CRASH OF A LARGE AIRPLANE AT NAAP

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
J73	8	6.0e+03	4.0e-10	2.5e-07	2.5e+03	2.0e-09	6.3e-07	2.5e+03	2.0e-09	6.5e-07	1.6e-06
J88	8	6.0e+03	4.0e-10	2.6e-07	2.5e+03	2.0e-09	6.3e-07	2.6e+03	2.0e-09	6.3e-07	1.5e-06
V171	8	2.0e+03	4.0e-10	1.0e-07	1.2e+03	2.0e-09	3.2e-07	2.6e+03	2.0e-09	5.9e-07	9.9e-07
V434	10	2.0e+03	4.0e-10	8.0e-08	1.2e+03	2.0e-09	2.4e-07	2.0e+03	2.0e-09	4.6e-07	7.2e-07

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
ROWE	8	0.0e+00	1.4e-09	0.0e+00	0.0e+00	1.4e-09	0.0e+00	0.0e+00	7.0e-09	0.0e+00	0.0e+00
										TOTAL	4.6e-06

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-9
CRASH OF A SMALL AIRPLANE AT NAAP

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
J73	8	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00
J00	8	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00
V[illegible]	8	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	3.5e+04	2.0e-09	8.7e-06	8.7e-06
V[illegible]34	10	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	3.5e+04	2.0e-09	7.0e-06	7.0e-06

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
ROME	8	0.0e+00	1.1e-09	0.0e+00	0.0e+00	1.4e-09	0.0e+00	1.0e+03	7.0e-09	7.0e-06	7.0e-06
										TOTAL	2.3e-05

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-10
CRASH OF A LARGE AIRPLANE AT PBA

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
J42	8	6.0e+03	4.0e-10	2.5e-07	2.6e+03	2.0e-09	8.3e-07	2.6e+03	2.0e-09	8.3e-07	1.5e-06

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
NONE											0.0e+00
										TOTAL	1.5e-06

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-11
CRASH OF A SMALL AIRPLANE AT PBA

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
342	8	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00
-	9	4.0e+02	4.0e-10	2.0e-08	2.4e+02	2.0e-09	6.0e-08	4.0e+02	2.0e-09	1.0e-07	1.8e-07

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
NONE											0.0e+00
										TOTAL	1.8e-07

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-12
CRASH OF A LARGE AIRPLANE AT PUDA

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
J20	8	1.0e+03	4.0e-10	6.0e-08	6.0e+02	2.0e-09	1.3e-07	6.0e+02	2.3e-08	1.1e-07	3.2e-07
J17	10	1.0e+03	4.0e-10	4.0e-08	6.0e+02	2.0e-09	1.0e-07	6.0e+02	2.0e-08	1.0e-07	2.4e-07
V10-244	8	4.0e+02	4.0e-10	2.0e-08	2.4e+02	2.0e-09	6.0e-08	4.0e+02	2.0e-08	1.0e-07	1.8e-07
V19-81	8	4.0e+02	4.0e-10	2.0e-08	2.4e+02	2.0e-09	6.0e-08	4.0e+02	2.0e-08	1.0e-07	1.8e-07
V81	10	4.0e+02	4.0e-10	1.6e-08	2.4e+02	2.0e-09	4.8e-08	4.0e+02	2.0e-08	8.0e-08	1.4e-07
V389	10	4.0e+02	4.0e-10	1.6e-08	2.4e+02	2.0e-09	4.8e-08	4.0e+02	2.0e-08	8.0e-08	1.4e-07

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
PUEBLO MEMORIAL	8	9.1e+03	1.4e-09	1.3e-05	9.1e+03	1.4e-09	1.3e-05	4.4e+03	7.8e-09	3.2e-05	5.8e-05
										TOTAL	5.9e-05

N = Number of flights per year
C1 = Probability of a crash per mile
C2 = Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-1[illegible]

CRASH OF A SMALL AIRPLANE AT PUDA

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
J20	8	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00
J17	10	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00
V10-244	8	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	7.0e+03	2.0e-09	1.7e-06	1.7e-06
V10-83	8	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	7.0e+03	2.0e-09	1.7e-06	1.7e-06
V81	10	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	7.0e+03	2.0e-09	1.4e-06	1.4e-06
V389	10	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	7.0e+03	2.0e-09	1.4e-06	1.4e-06

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
PUEBLO MEMORIAL	8	0.0e+00	1.4e-09	0.0e+00	0.0e+00	1.4e-09	0.0e+00	1.4e+04	7.0e-09	9.8e-05	9.8e-05
										TOTAL	1.0e-04

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-14

CRASH OF A LARGE AIRPLANE AT TEAD

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
V267	8	8.0e+02	4.0e-10	4.0e-08	4.8e+02	2.8e-09	1.2e-07	8.0e+02	2.0e-09	2.0e-07	3.6e-07

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
NONE											0.0e+00
										TOTAL	3.6e-07

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-15

CRASH OF A SMALL AIRPLANE AT TEAD

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
V257	0	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	1.4e+04	2.0e-09	3.5e-08	3.5e-08

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
NONE											0.0e+00
										TOTAL	3.5e-08

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-16
CRASH OF A LARGE AIRPLANE AT UMDA

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
J64	8	1.0e+04	4.0e-10	6.0e-07	6.0e+03	2.0e-09	1.3e-08	6.0e+03	2.0e-09	1.3e-06	8.9e-08
J20	12	1.0e+04	4.0e-10	3.3e-07	6.0e+03	2.0e-09	8.3e-07	6.0e+03	2.0e-09	8.3e-07	[illegible]
V4	12	4.0e+03	4.0e-10	1.3e-07	2.4e+03	2.0e-09	4.0e-07	4.0e+03	2.0e-09	6.7e-07	1.2e-08
VR1364	6	0.0e+00	4.0e-10	0.0e+00	2.6e+04	2.0e-09	6.3e-08	0.0e+00	2.0e-09	0.0e+00	8.3e-08

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
NONE											0.0e+00
										TOTAL	1.6e-06

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-17
CRASH OF A SMALL AIRPLANE AT UMDA

AIRWAYS

ROUTE	ROUTE WIDTH	COMMERCIAL N	COMMERCIAL C1	COMMERCIAL P	MILITARY N	MILITARY C1	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C1	GENERAL AVIATION P	ALL P
J64	8	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00
J20	12	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00
V4	12	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	7.0e+04	2.0e-09	1.2e-06	1.2e-06
VR1354	8	0.0e+00	4.0e-10	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00	2.0e-09	0.0e+00	0.0e+00

AIRPORTS

AIRPORT	MILES TO SITE	COMMERCIAL N	COMMERCIAL C2	COMMERCIAL P	MILITARY N	MILITARY C2	MILITARY P	GENERAL AVIATION N	GENERAL AVIATION C2	GENERAL AVIATION P	ALL P
NONE											0.0e+00
										TOTAL	1.2e-06

N = Number of flights per year
C1= Probability of a crash per mile
C2= Probability of a crash per sq. mile
P = Probability of a crash per sq. mile per year

TABLE C-18
EFFECTIVE AREAS OF CRASH SITES[a]

Storage Facility	Large Aircraft Direct Crash	Large Aircraft Adjacent Crash	Small Aircraft Direct Crash
80-ft igloo	7.6E-5	4.8E-5	0.0E+0
60-ft igloo	5.7E-5	3.7E-5	0.0E+0
40-ft igloo	3.8DE-5	2.4E-5	0.0E+0
89-ft magazine	8.2E-5	4.6E-5	0.0E+0
Warehouse at TEAD	2.4E-3	2.4E-3	3.0E-3
Warehouse at UMDA	1.6E-3	1.8E-3	2.1E-3
Warehouse at NAAP	7.9E-4	1.7E-3	1.3E-3
Open storage at APG	4.6E-3	4.9E-3	5.7E-3
Open storage at PBA	1.1E-2	6.6E-3	1.3E-2
Open storage at TEAD	2.2E-2	1.2E-2	2.5E-2
Train (50 cars)	1.1E-2	1.6E-2	5.4E-3
ECR	5.4E-5	--	--
UPA	2.4E-4	--	1.6E-4
TOX	4.1E-5	--	--
Truck	3.6E-4	--	9.0E-5
Outside agent piping at TEAD	1.8E-3	--	5.9E-4

[a]Units of area is square miles.

C.1.7. REFERENCES

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C-3. "Standard for Estimating Tornado and Extreme Wind Characteristics at Nuclear Power Sites," ANSI/ANS-2.3-1983, 1983.

C-4. Coats, D. W., "National Phenomena Hazards Modeling Project: Extreme Wind/Tornado Hazard Models for Department of Energy Sites," UCRL-53526, Lawrence Livermore National Laboratory, February 1984.

C-5. "Tentative Provisions for the Development of the Seismic Regulations for Buildings," Applied Technology Council, ATC 3-06, NBS SP-510, NSF 78-8, June 1978.

C-6. "Structural Analysis and Design of Nuclear Plant Facilities," American Society of Civil Engineers, Manuals and Reports on Engineering Practice No. 58, 1980.

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C-8. Blake, V. E., "A Prediction of the Hazards from the Random Impact of Meteorites on the Earth's Surface," Sandia Laboratories SC-RR-86-838, December 1968.

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APPENDIX D
SITE INFORMATION

D.1. SITE INFORMATION

This appendix discusses the location and characteristics of the eight CONUS sites where chemical munitions are stored and provides a brief description of the storage areas. Figure D-1 shows the general location of the eight sites. The site characteristics discussed included recorded earthquake activity and aircraft patterns in the vicinity.

D.1.1. ABERDEEN PROVING GROUND

As shown in Figs. D-2 and D-3, the Aberdeen Proving Ground (APG) is located in Harford County, Maryland near the head of the Chesapeake Bay.

APG is a Test and Evaluation Command (TECOM) installation within U.S. Army Materiel Command (AMC). The main activities/mission of APG include testing and evaluating vehicles, munitions, and other combat hardware. A major tenant activity, the Chemical Research, Development, and Engineering Center (CRDEC), is located at APG.

APG is comprised of two general areas, the Aberdeen Area and Edgewood Area. The Edgewood Area is situated adjacent to the town of Edgewood in the southwestern part of Harford County. There have occurred in the vicinity of the APG site 48 recorded earthquakes of Modified Mercalli Intensity (MMI) levels from I to VII, as summarized in Table D-1.

The chemical storage area at APG is located in the northeast corner of the Edgewood Area The Chemical Agent Storage Yard (CASY) is an open area encompassing approximately 5 acres and is situated along the Bush

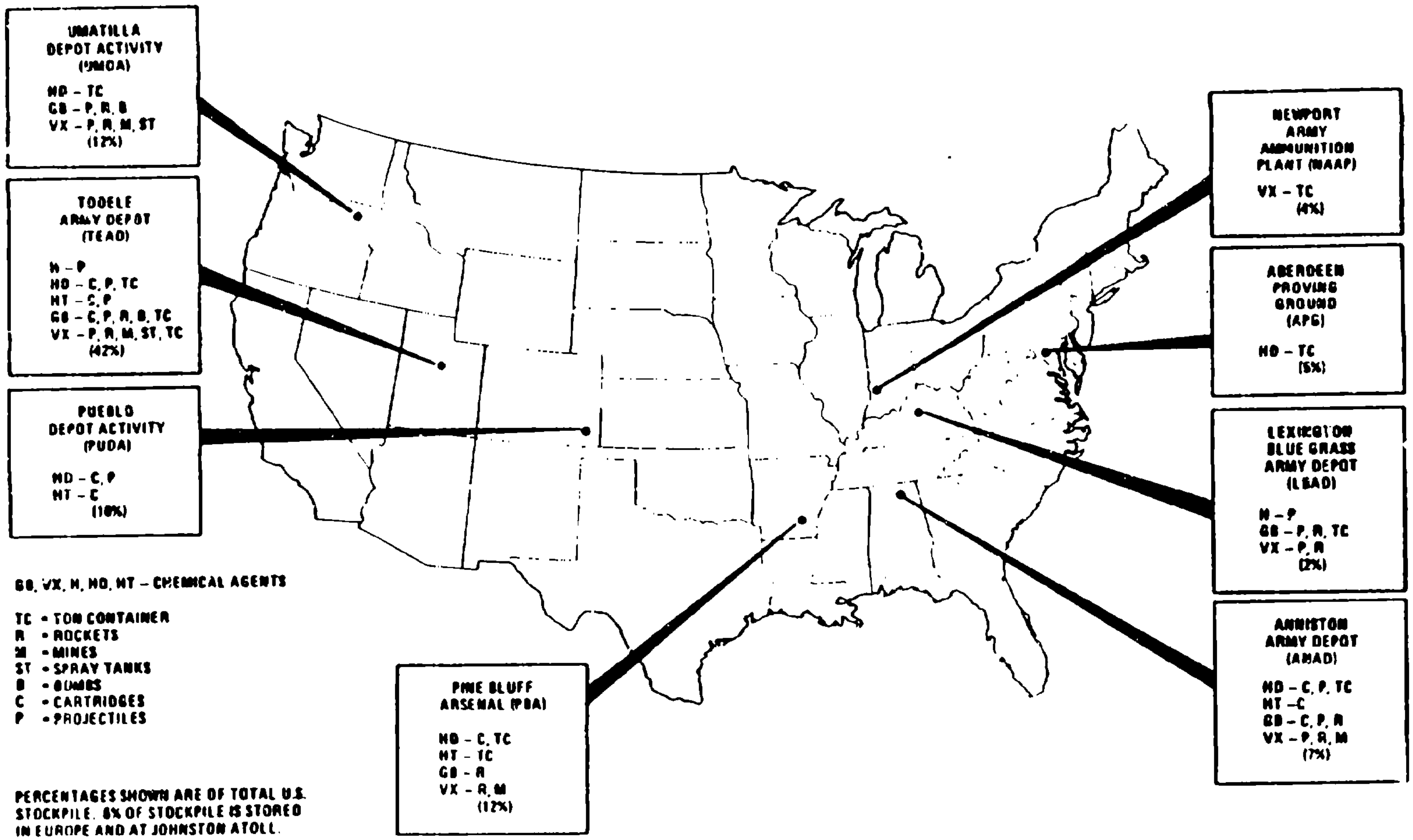

Fig. D-1. Location of chemical agents and munitions in the U.S.

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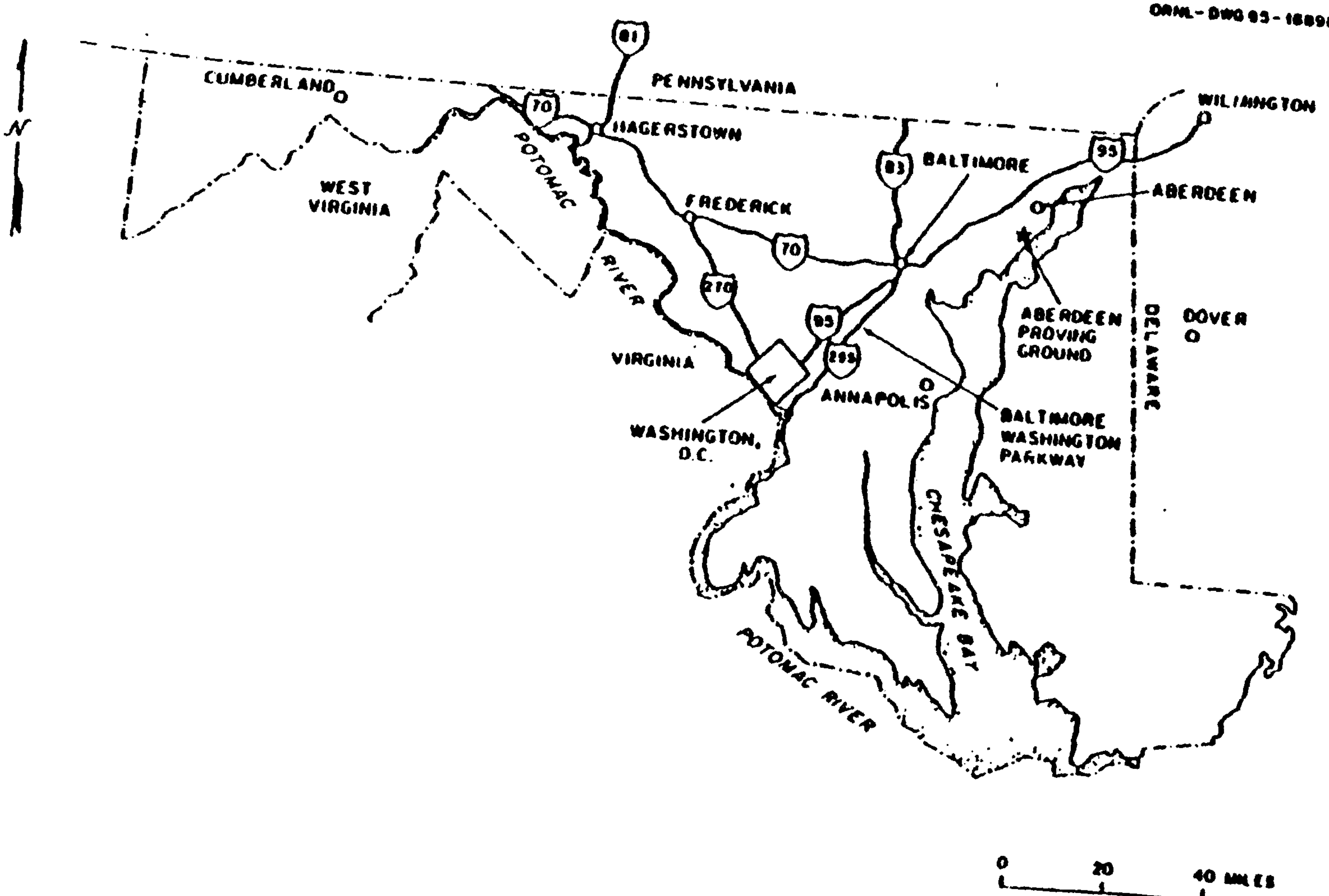

Fig. D-2. Maryland state map showing the location of APG

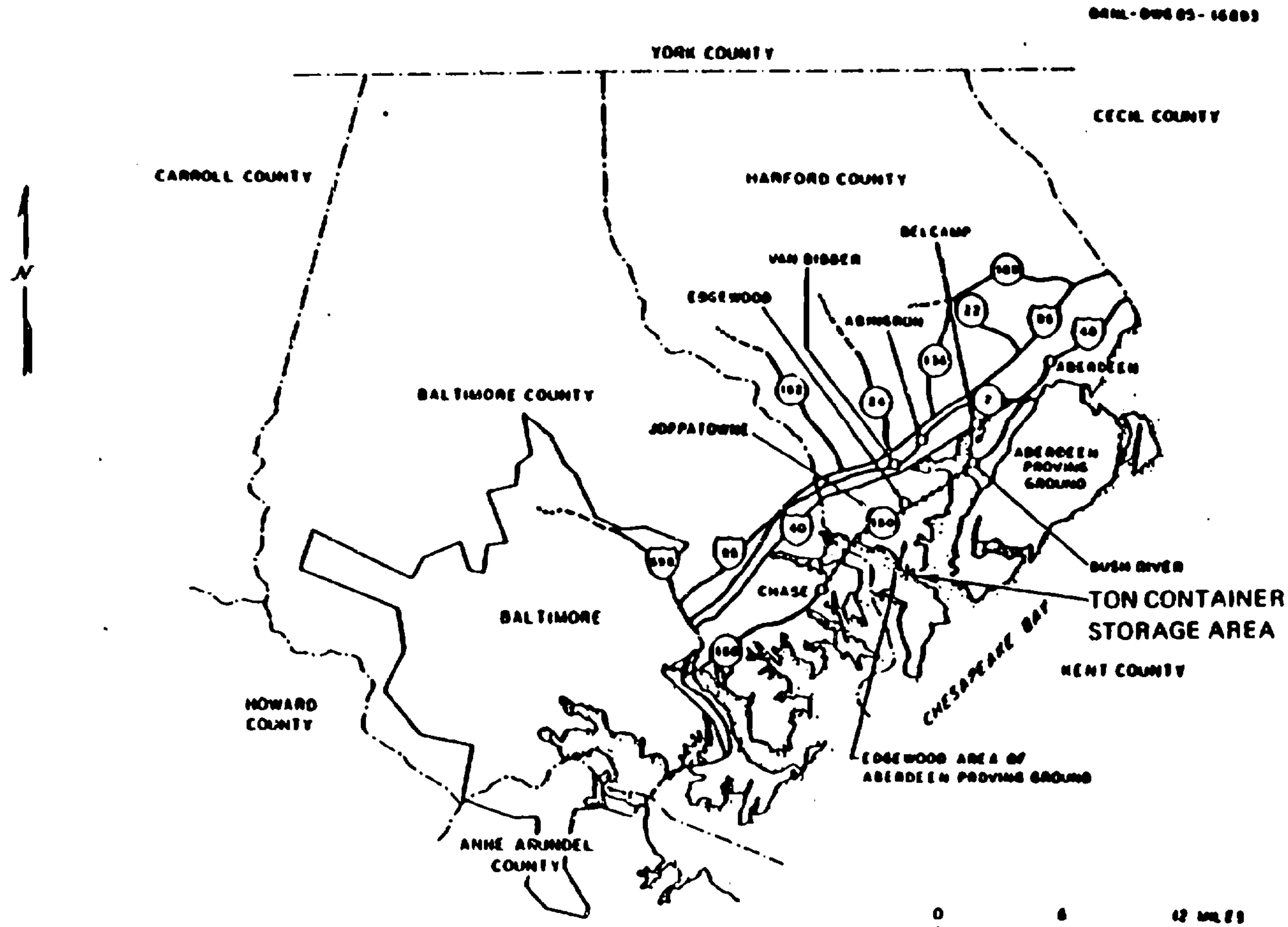

Fig. D-3. County map showing the location of APG

TABLE D-1
EARTHQUAKES IN THE VICINITY OF THE APG SITE
(Ordered By Distance From Site)

Year	Month	Day	Location	MMI	Distance from Site (km)
1883	3	11	39.5N, 76.4W	V	14
1883	3	12	39.5N, 76.4W	V	14
1883	3	12	39.5N, 76.4W	III	14
1883	3	12	39.5N, 76.4W	V	14
1939	6	22	39.5N, 76.6W	III	28
1939	11	18	39.5N, 76.6W	IV	28
1939	11	26	39.5N, 76.6W	V	28
1930	11	01	39.1N, 76.5W	IV	38
1930	11	01	39.1N, 76.5W	III	38
1906	10	13	39.2N, 76.7W	III	41
1910	04	24	39.2N, 76.7W	III	41
1758	04	25	38.9N, 76.5W	V	58
1876	01	30	38.9N, 76.5W		58
1978	07	16	39.9N, 76.2W	V	58
1984	04	19	39.9N, 76.3W	V	58
1984	04	23	39.9N, 76.3W	V	58
1910	01	24	39.6N, 77.0W	II	64
1828	02	24	38.9N, 76.7W		65
1978	10	06	39.9N, 76.5W	VI	66
1885	03	09	40.0N, 76.3W	IV	67
1939	04	02	40.0N, 76.3W	II	67
1971	07	14	39.7N, 75.6W	IV	69
1971	12	29	39.7N, 75.6W	IV	69
1972	01	02	39.7N, 75.6W	IV	69
1972	01	03	3917N, 75.6W	IV	69
1972	01	07	39.7N, 75.6W	IV	69
1972	01	22	39.7N, 75.6W	IV	69
1972	01	23	39.7N, 75.6W	IV	69
1972	01	23	39.7N, 75.6W	IV	69
1972	02	11	39.7N, 75.6W	V	69
1972	02	11	39.7N, 75.6W		69
1972	08	14	39.7N, 75.6W	IV	69
1972	08	14	39.7N, 75.6W		69
1974	04	28	39.7N, 75.6W	IV	69
1889	03	08	40.0N, 76.0W	V	71
1889	03	09	40.0N, 76.0W		71
1871	10	10	39.6N, 75.5W	IV	72
1879	03	26	39.2N, 75.5W	V	72
1902	03	10	39.6N, 77.1W	III	72
1902	03	11	39.6N, 77.1W	III	72
1903	01	01	39.6N, 77.1W	I	72
1983	11	17	39.8N, 75.6W	V	73
1983	12	12	39.8N, 75.6W		73
1871	10	09	39.7N, 75.5W	VII	76
1902	03	10	39.6N, 77.2W	III	80
1902	03	11	39.6N, 77.2W	III	80
1903	01	01	39.6N, 77.2W	III	80
1903	01	01	39.6N, 77.2W	II	80

Data provided by the National Geophysical Data Center, NOAA.

River. The storage yard consists of a central aisleway of finished concrete and the ton containers are secured over a gravel surface. There are two buildings in the CASY that are used to store equipment. Only mustard-filled ton containers are stored at APG and they are stored outdoors in accordance with AMC regulations.

The airspace above the Edgewood area of APG is continuously restricted (Restriction No. R-4001A). Permission to fly at altitudes above 10,000 ft from midnight to 7:00 AM may be requested 24 hr in advance. The Weide Army Air Field (AAF) is located within a mile of the storage area. It has a 4600-ft runway which is used by a general aviation flying club and an Air National Guard helicopter unit located at Weide AAF. The Army estimates that there are approximately 2600 general aviation operations (takeoffs/landings), 7200 helicopter operations, and 800 small fixed-wing military operations per year at Weide. There are no large aircraft operations.

Phillips AAF is located approximately 8 miles to the northeast. It has three runways. The longest is 8000 ft. The Army indicates that the edges of the approach and holding patterns for Phillips are more than 2 miles north of the storage area. Therefore, they are not considered a threat to the storage area per the guideline of Ref. D-3.

There are three other airports located in the area. Baltimore Airpark is approximately 8 miles to the west and has one 2200-ft runway. Martin State Airport is located 8 miles to the southeast. It has three runways. The longest is 7000 ft. The largest airport in the area is Baltimore Washington International Airport which is 26 miles southwest of Aberdeen. Its longest runway is 9500 ft. There are two low altitude federal airways (V378 and V499) that pass approximately 8 miles from the storage area. The closest high altitude jet routes (J42-8 and J40) are approximately 14 miles from the storage area. These airports and airways are not expected to present a significant threat to the storage area because of the distances involved and because the storage area is protected by the restricted airspace.

D.1.2. ANNISTON ARMY DEPOT

As shown in Figs. D-4 and D-5, the Anniston Army Depot (ANAD) is located within Calhoun County in northeast Alabama adjacent to Fort McClellan, another active U.S. Army installation. ANAD is a major supply, stock distribution, and storage depot for general and strategic material, equipment, and supplies, including ammunition. Its functions also include maintenance and disposal activities associated with ammunition supply and storage, such as ammunition preservation, demilitarization, surveillance and training.

The chemical storage area at ANAD is located along the northeastern edge of the installation. The chemical storage area is divided into two adjacent areas, G-block and C-block. The ANAD chemical munition stockpile consists of all munition types except bombs and spray tanks. Munitions are stored in 40-ft, 60-ft, and 80-ft igloos. All 40-ft and 60-ft igloos are equipped with a single door, while all 80-ft igloos are equipped with a double door. The igloos are well maintained with no evidence of chronic structural problems. All igloos were re-waterproofed in 1984. The re-waterproofing involved removing the earthen covering over the igloo and sealing the concrete surface with tar. The earthen cover was then replaced to specifications.

The stockpile of chemical munitions stored at ANAD includes 105-mm cartridges, 4.2-in. mortars, 155-mm and 8-in. projectiles, 115-mm rockets, land mines, and ton containers. Documentation indicates that all of the 105-mm projectiles are stored in the cartridge configuration, packaged two cartridges per box. All munitions are stored in their standard configurations in accordance with AMC regulations.

As shown in Table D-2, five earthquakes of MMI levels V to VII have occurred in the vicinity of the ANAD site in this century.

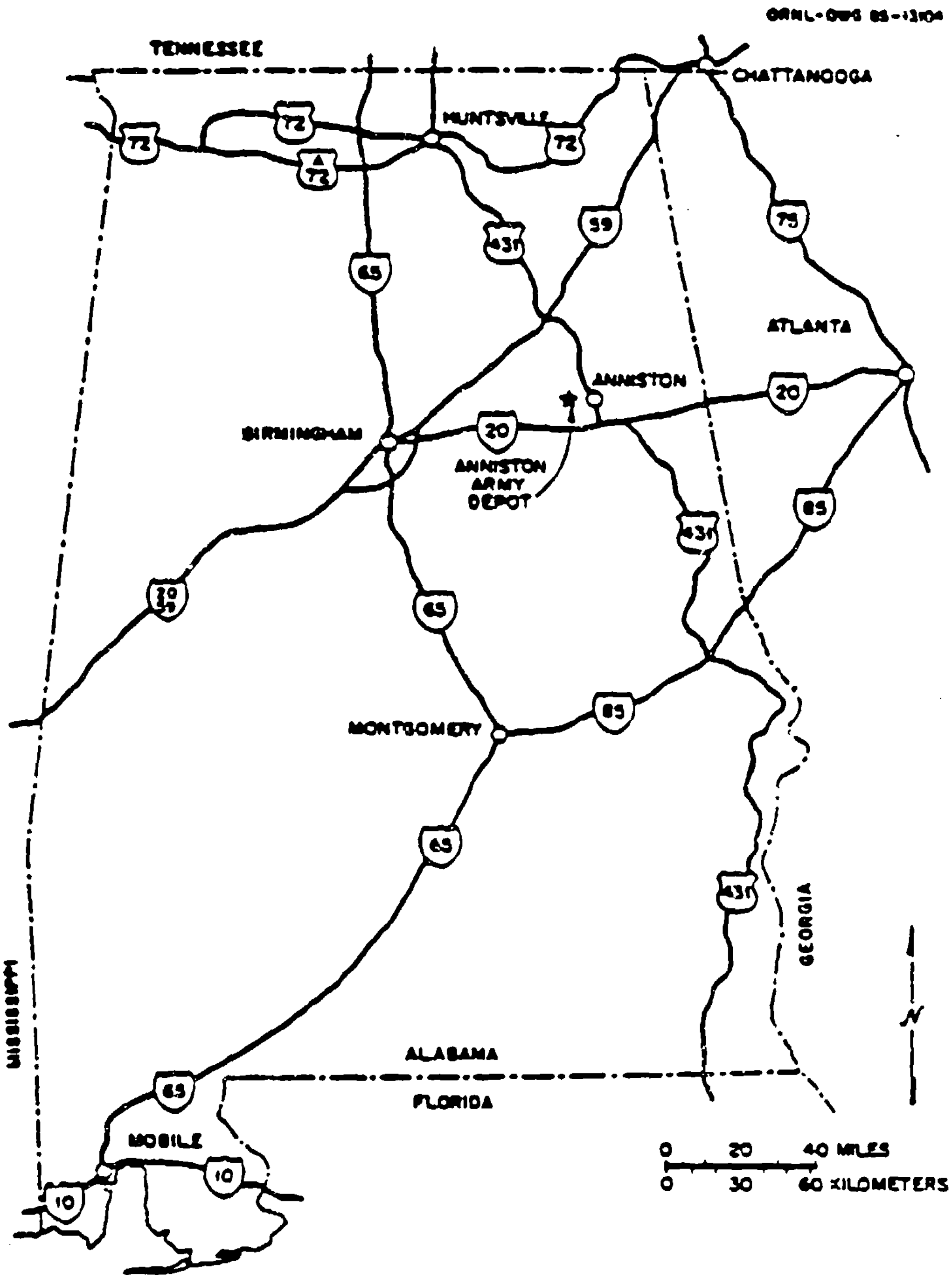

Fig. D-4. Alabama state map showing the location of ANAD

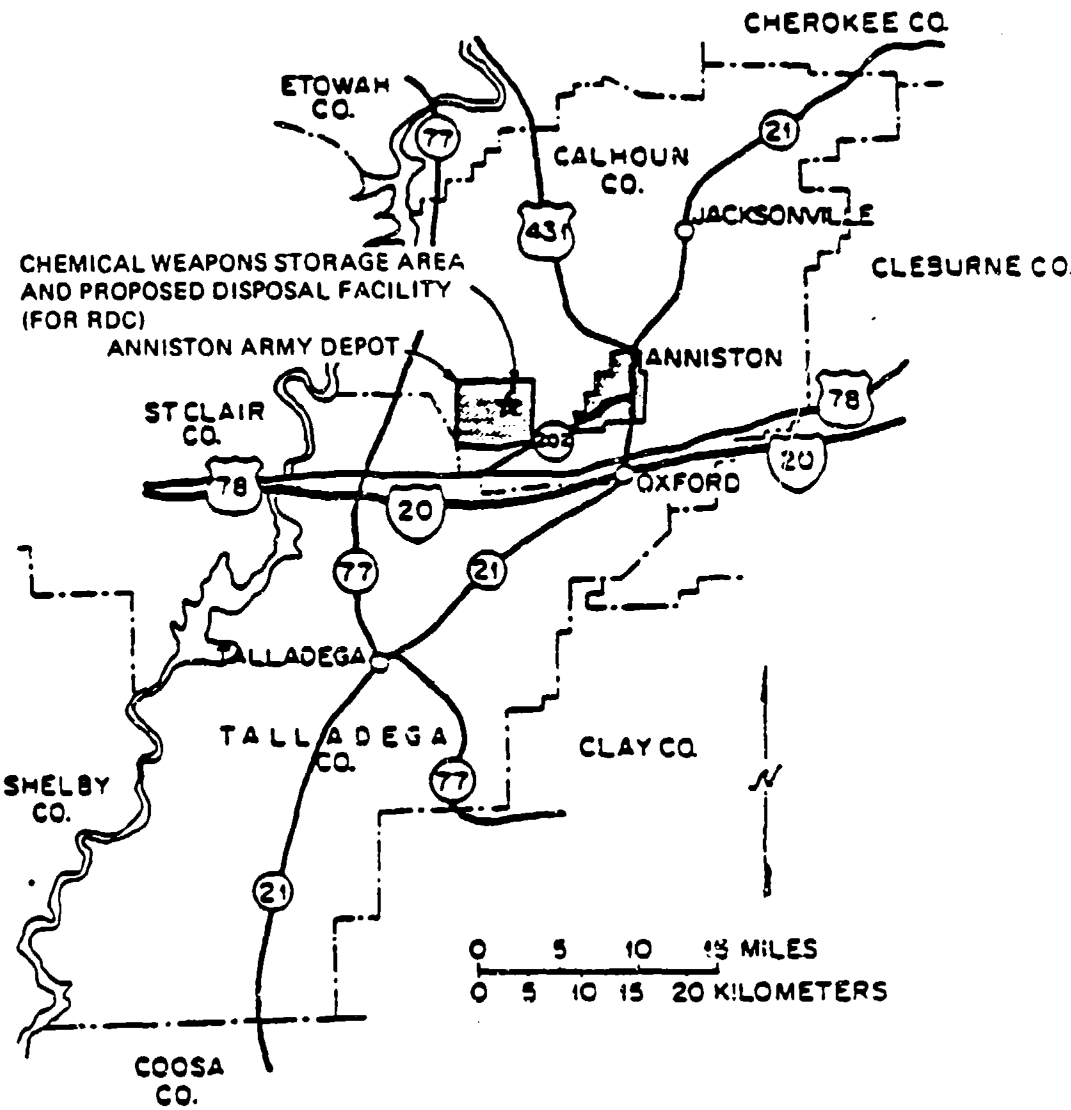

Fig. D-5. County map showing the location of ANAD

TABLE D-2
EARTHQUAKES IN THE VICINITY OF THE ANAD SITE[a]
(Chronological Listing)

Year	Month	Day	Location	Epicentral Intensity (MMI)
1916	10	18	Irondale, AL 33.5N, 86.2W	VII
1927	6	16	Scottsboro, AL 34.7N, 86.0W	V
1931	5	5	Cullman, AL 33.7N, 86.6W	V to VI
1939	5	4	Anniston, AL 33.7N, 85.8W	V
1975	8	28	Northern, AL 33.3N, 86.6W	VI

[a]Earthquakes within a 50- to 60-mile radius of the Anniston site, abstracted from Table 2.5-2, Clinch River Breeder Reactor Plant Preliminary Safety Analysis Report. Source: Ref. D-1.

The airspace above the chemical munition storage area at the ANAD is unrestricted. The airspace just north and northeast of the chemical storage area is restricted continuously to 24,000 ft (Restriction number R-2102). The area just west of the chemical munition storage area is restricted up to a 5000-ft level from 7:00 AM to 6:00 PM Monday through Friday (Restriction number R-2101).

The closest major airfields are Anniston and Talladega, both of which are approximately 8 miles from the chemical munition storage area. Anniston has a 7000-ft runway and can accept aircraft as large as a Lockheed C-141. Air traffic flying in and out of Anniston must stay to the south of the depot (Ref. D-1). Talladega has a 6000-ft runway. It has handled Lockheed C-130s but cannot accept C-141s. Air traffic coming out of Talladega must stay west of the depot (Ref. D-1). Consequently, the edge of the flight path in and out of Anniston and out of Talladega is at least 2 miles from the storage area.

To the east and north of the city of Anniston, there are two small airports and a heliport, the closest of which is 8 miles from the storage area. Air traffic from these airports is not a significant threat to the storage area since there is 3 miles of restricted airspace between these airports and the storage area.

There is one low altitude federal airway (V18) which passes 6 miles south of the storage area and one high altitude jet route (J14-52) which passes directly above the storage area. The high altitude jet route is the preferred jet route for air traffic between Atlanta and Denver (Ref. D-2). Military training route IR69 passes over the storage area and then returns three miles south of the storage area.

D.1.3. LEXINGTON-BLUE GRASS ARMY DEPOT

As shown in Figs. D-6 and D-7, the Lexington-Blue Grass Army Depot (LBAD) is located in Madison County, south of Richmond, Kentucky. The primary mission of the depot is to operate a general supply and ammunition depot activity providing for the receipt, storage, issue, maintenance, demilitarization, and disposal of assigned commodities.

The chemical munition storage area at LBAD is located in the north central half of the Blue Grass facility. The chemical munition stockpile at LBAD consists of 8-in. projectiles, 155-mm projectiles, and M55 rockets. These munitions are stored in 89-ft oval-arch igloos. Seventy-five percent of the igloos were waterproofed in 1982. The procedure involved removing the earth covering the igloo to apply a layer of tar, and then replacing the earthen cover.

Table D-3 summarizes earthquake activity in the vicinity of the LBAD site.

LBAD airspace is not restricted. There are three small airfields in the vicinity of the depot: Madison County Airport, Berea Richmond Airfield, and Galla Airfield. Madison County Airport is approximately 9 miles from the storage area. At the Madison County Airport, there is a civilian flight school which operates light aircraft, ranging from single engine light planes up to twin engine aircraft. The flight school uses two training areas near the depot, one to the north and the other to the east. The Madison County airport has a 4000-ft runway. The Berea Richmond Airfield is approximately 6 miles from the storage area and can support only light aircraft on its 2400-ft grass strip runway. Galla is a small, private airfield 12 miles east of the storage area. The air traffic from these airports over the storage area is not expected to be a significant hazard.

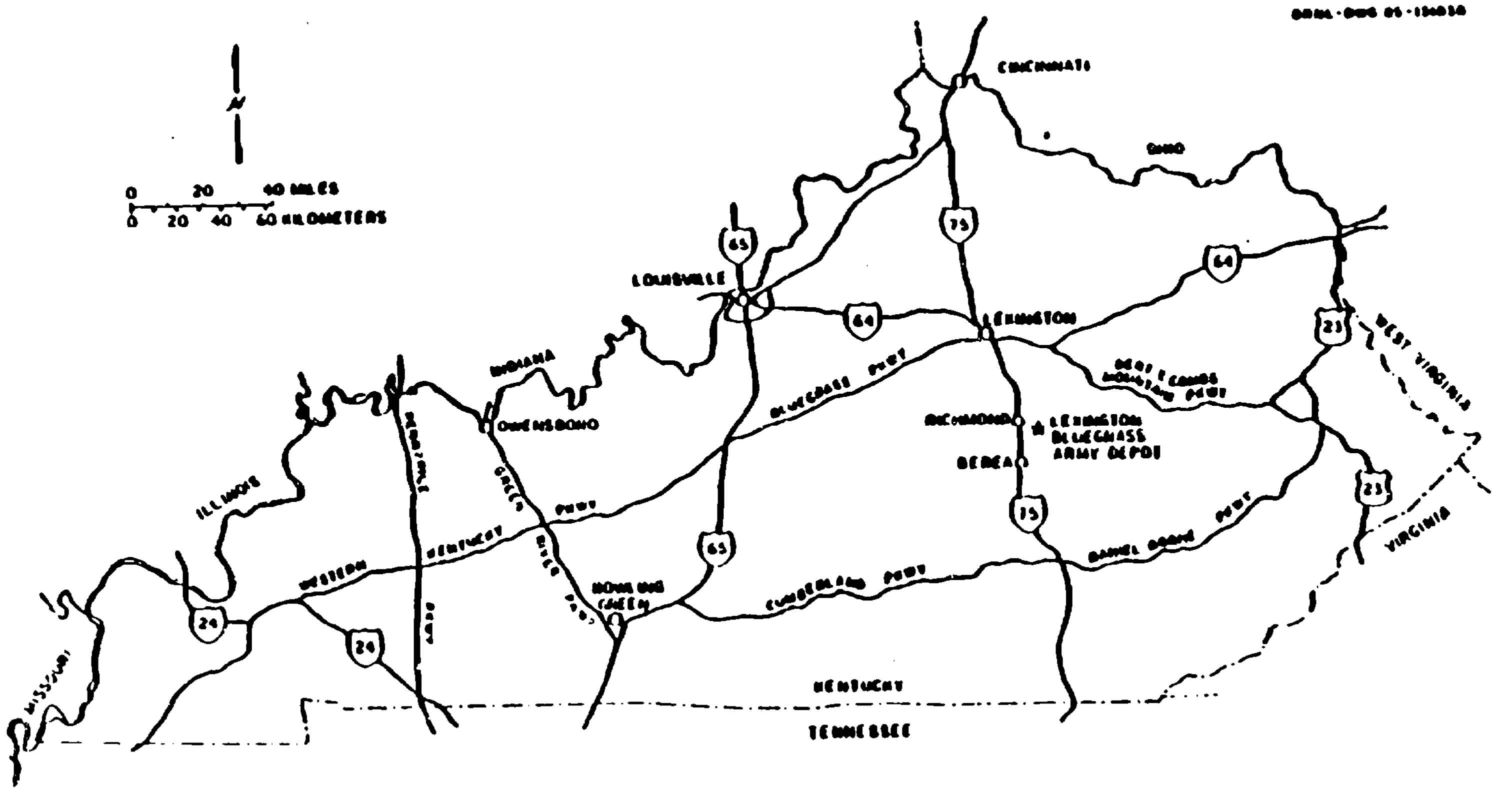

Fig. D-6. Kentucky state map showing the location of LBAD

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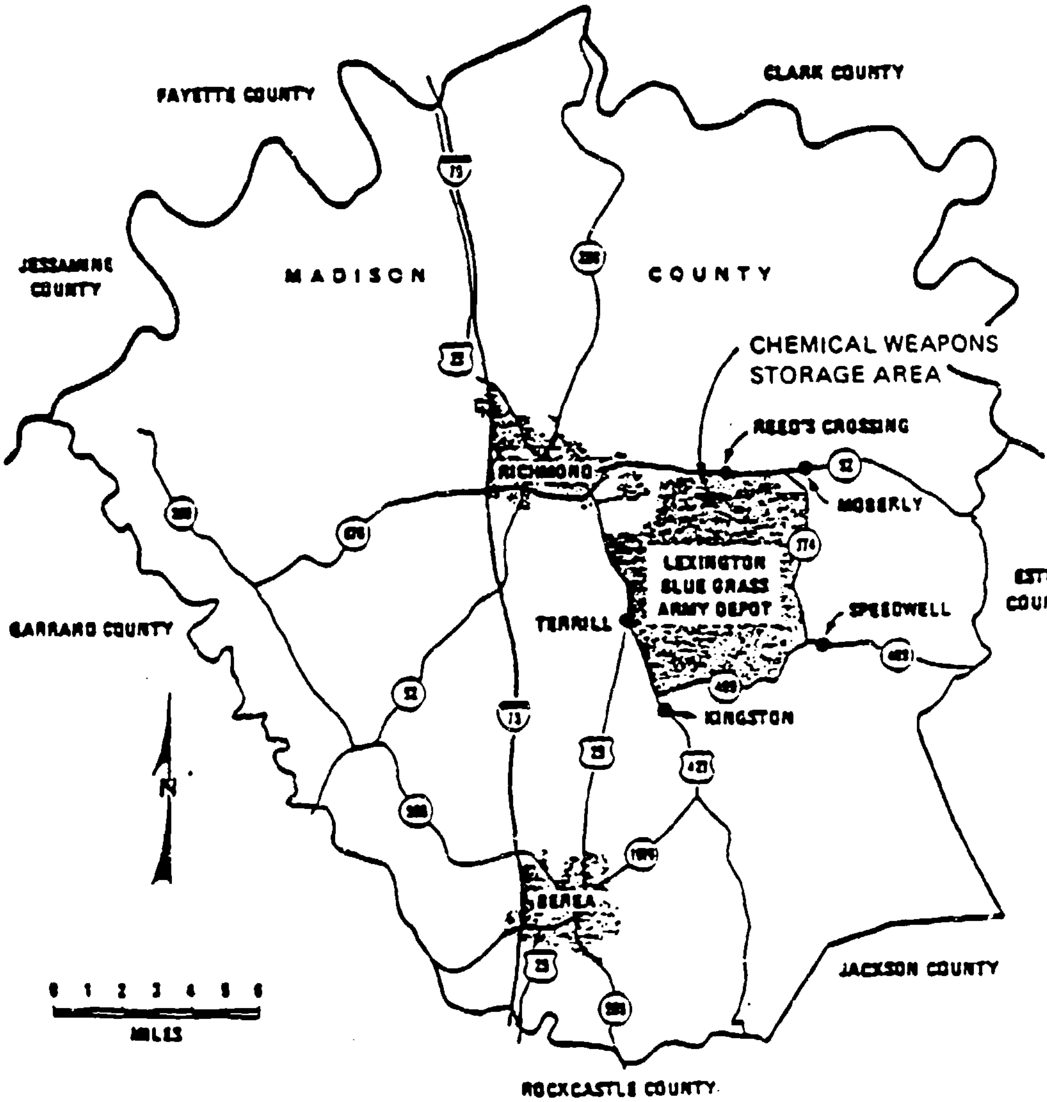

Fig. D-7. Madison county map showing the location of LBAD

TABLE D-3
EARTHQUAKES IN THE VICINITY OF THE LBAD SITE[a]
(Chronological Listing)

Year	Month	Day	Location	Epicentral Intensity (MMI)
1779	1	1	Kentucky 38.0N, 84.0W	Unknown
1834	11	20	Northern KY 37.0N, 86.0W	V
1933	5	28	Maysville, KY 38.7N, 83.7W	V
1954	1	1	Middlesboro, KY 36.6N, 83.7W	VI
1968	12	11	Louisville, KY 38.0N, 85.5W	V
1974	6	4	Kentucky 38.6N, 84.77W	V (est)
1976	1	19	Kentucky 36.88N, 83.82W	VI
1979	11	9	NE Kentucky 38.42N, 82.88W	V (est)
1980	6	27	Kentucky 38.17N, 83.91W	VII
1980	8	2	Kentucky 37.99N, 84.92W	III
1980	8	22	Kentucky 37.99N, 84.92W	III

[a]Earthquakes within a 50- to 60-mile radius of the Lexington-Blue Grass Site, abstracted from Table 2.5-2, Clinch River Breeder Reactor Plant Preliminary Safety Analysis Report. Source: Ref. D-1.

There is a U.S. Air Force radar bombing/scoring detachment stationed at the LBAD with frequent flights (10 to 11 aircraft per day) of Air Force B-52, F-4, and F-111 aircraft at low altitudes (750 and 3000 ft). The flights are active from 11:30 AM to 3:30 PM and from 6:00 PM until midnight every day. They fly at 750 ft under visual flight rules and at 2000 to 3000 ft under instrument rules with a visual observer. Generally, they make three simulated bombing runs per flight at distances at least 2 miles away from the chemical exclusion area. Per the guidelines of Ref. D-3, this is not expected to be a significant problem.

D.1.4. NEWPORT ARMY AMMUNITION PLANT

The Newport Army Ammunition Plant (NAAP) is located in west central Indiana, west of Indianapolis, as shown in Figs. D-8 and D-9. NAAP is operated by Mason & Hangar. The mission of NAAP is to (1) manufacture explosive and chemical materials, (2) fill chemical munitions, and (3) to store chemical munitions. Items 1 and 2 are currently inactive, while item 3 involves the activities associated with storage of VX chemical agent ton containers.

The chemical storage area at NAAP includes a single storage warehouse (Building 144) that is used to house VX ton containers. The storage building is approximately 79 ft wide and 279 ft long. The walls and roof of the building are of heavy gauge corrugated sheet metal, supported by steel beams.

The warehouse is in an exclusion area adjacent to the former VX production facility. The grounds within the exclusion area are all concrete or macadam covered surfaces. There are several large storage tanks that were used to store agent which are located along the southeast side of the warehouse. These storage tanks are currently empty. A 409-ft tall flash tower is located 450 ft to the east of Building 144. The flash tower was utilized during production of VX to burn several flammable gas by-products. Just outside the exclusion area, approximately 560 ft to the east of Building 144, is the site of a natural gas metering station. Natural gas was distributed to the production plant and to the area boiler from this point. Several empty storage vessels are located approximately 350 ft from the nearest ton containers outside the exclusion area. These tanks were used in conjunction with the former VX production facility. These tanks are to remain empty during the demilitarization campaign.

Table D-4 summarizes earthquake activity in the vicinity of the NAAP site.

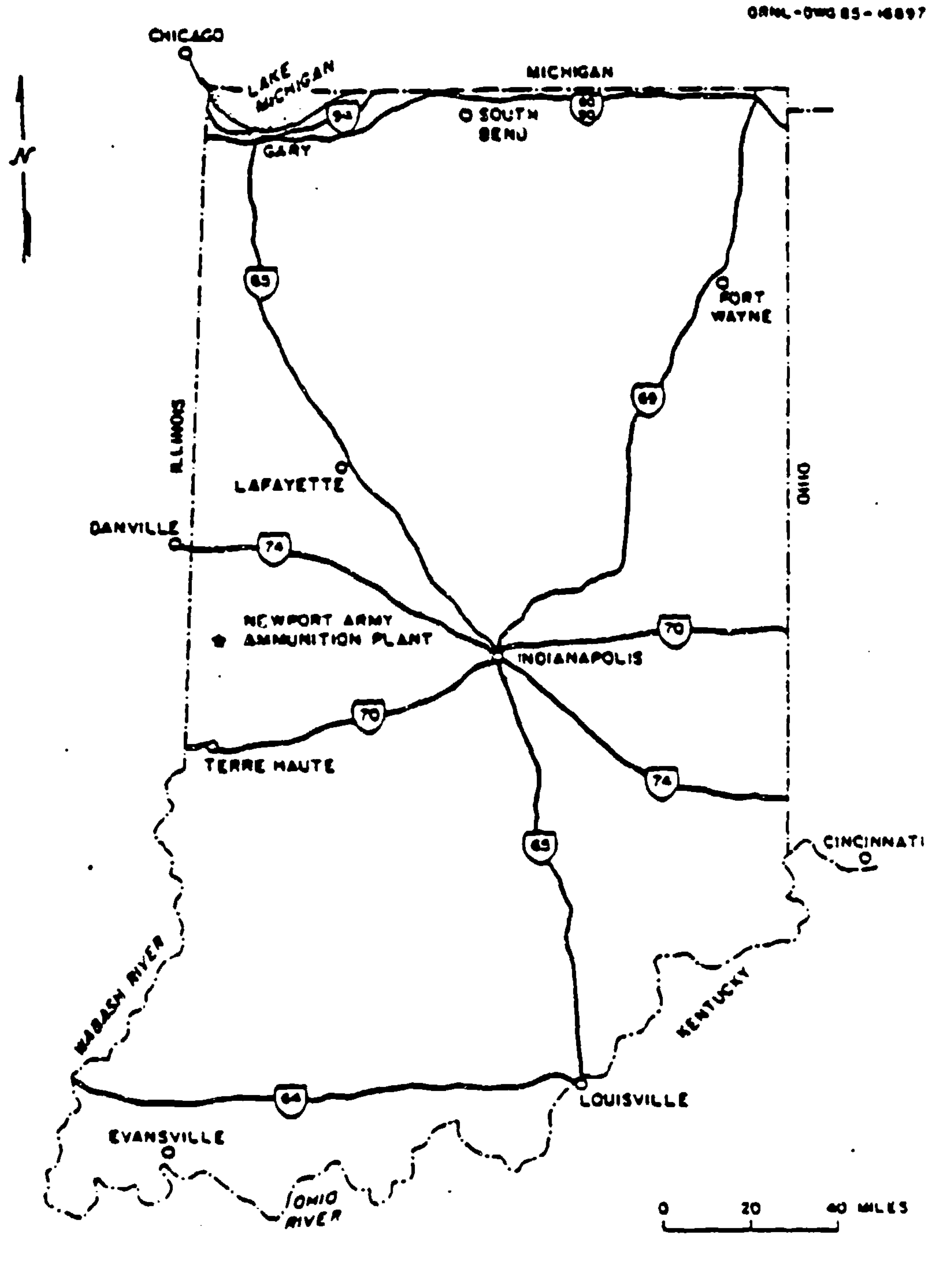

Fig. D-8. Indiana state map showing the location of NAAP

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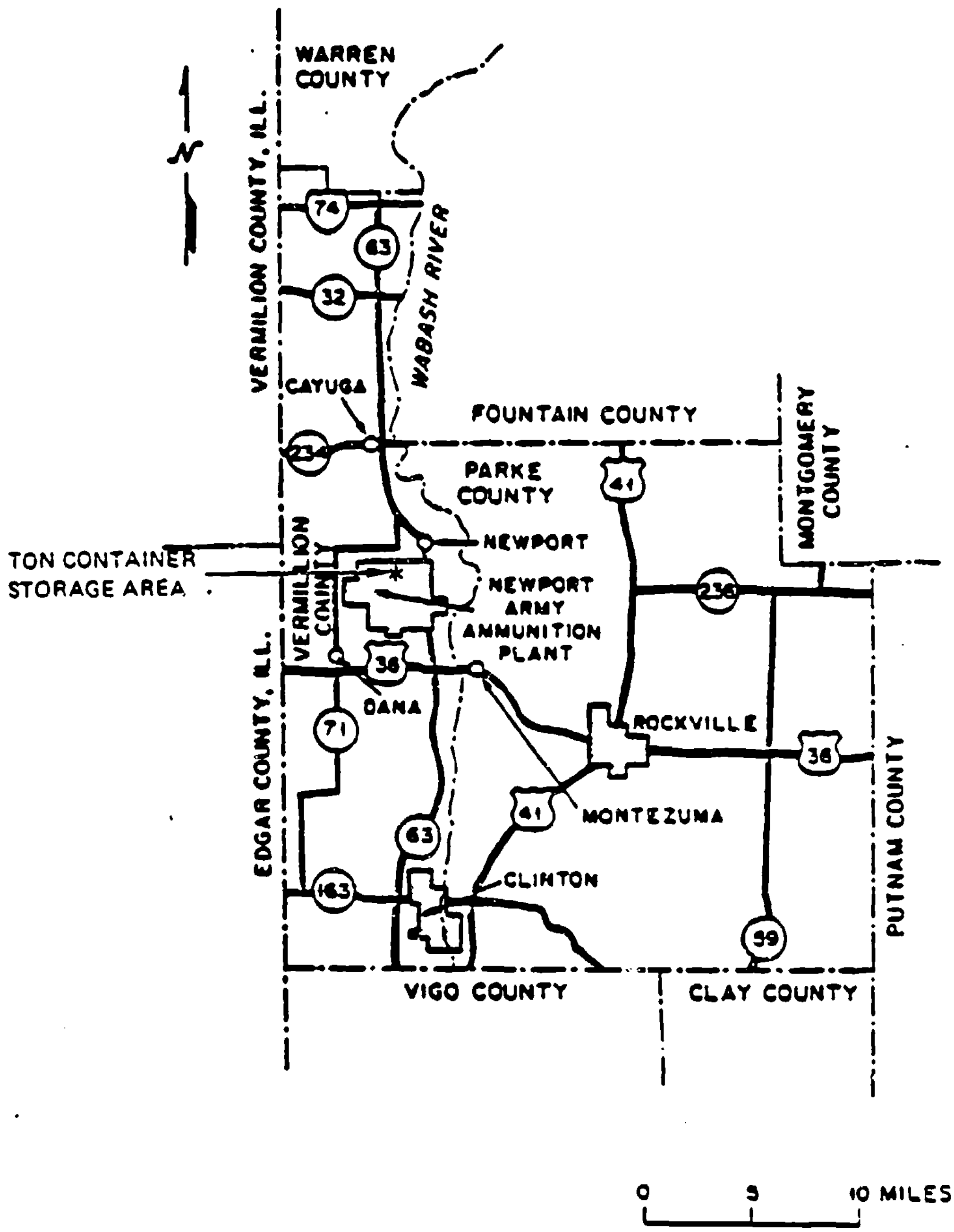

Fig. D-9. County map showing the location of NAAP

The airspace at NAAP is not restricted. The only airport within a 10-mile radius of the plant is a private airstrip (Rowe) with a 2600-ft runway located 8 miles west of the plant. The nearest public airport is Clinton which is approximately 12 miles south of the plant. Low altitude federal airway V171 passes 2 miles east of the storage area and airway V434 passes 5 miles north of the storage area. High altitude jet routes J80 and J73 cross over the storage area.

TABLE D-4
EARTHQUAKES IN THE VICINITY OF THE NAAP SITE
(Ordered By Distance From Site)

Year	Month	Day	Location	MMI	Distance from Site (km)
1909	9	27	39.5N, 87.4W	VII	41
1921	3	14	39.5N, 87.5W	IV	41
1903	12	31	40.0N, 87.9W		42
1974	11	25	40.3N, 87.4W	II	48
1906	7	13	39.7N, 86.8W		57
1906	8	13	39.7N, 86.8W	IV	57
1984	8	29	39.3N, 87.2W	V	58
1978	2	16	39.8N, 88.23W		68
1984	7	28	39.2N, 87.1W	V	78

Data provided by the National Geophysical Data Center, NOAA.

D.1.5. PINE BLUFF ARSENAL

As shown in Figs. D-10 and D-11, the Pine Bluff Arsenal (PBA) is located southeast of Little Rock, Arkansas and northwest of the city of Pine Bluff, Arkansas. The primary missions include storage of conventional and chemical munitions, destruction of nontoxic chemicals, and production of smoke munitions, white phosphorus projectiles and other incendiary devices. Future responsibilities include demilitarization of the BZ stockpile and production of binary chemical munitions.

The chemical storage area at PBA is located in the northwestern section of the installation. The following munitions are stored at PBA: 4.2-in. mortar projectiles, M55 rockets, land mines, and ton containers. All munitions except ton containers are stored in 80-ft igloos. Ton containers containing mustard agent are stored outdoors in a fenced area within the chemical storage area. The ton containers are strapped to railroad rails and stacked one high per AMC regulations.

Table D-5 summarizes earthquake activity in the vicinity of the PBA site.

PBA airspace is not restricted. The closest important airfield, Grider Field, is about 16 miles southeast of the chemical munition storage area. There are three smaller airfields which are closer (10 to 14 miles). Because of the relatively significant distances from airfields, PBA is not considered to have a significant hazard due to airfield operations.

Grider handles approximately 115 aircraft movements per day, seven days a week. About 95% of this traffic is corporate/civilian, and the remainder is military. The runway at Grider Field is 6,000 ft and can occasionally accommodate commercial 727 and military C-141 aircraft. Low altitude federal airways V74, V305, and V16 pass within 7, 10, and 11 miles, respectively. High altitude airway J42 passes over the site.

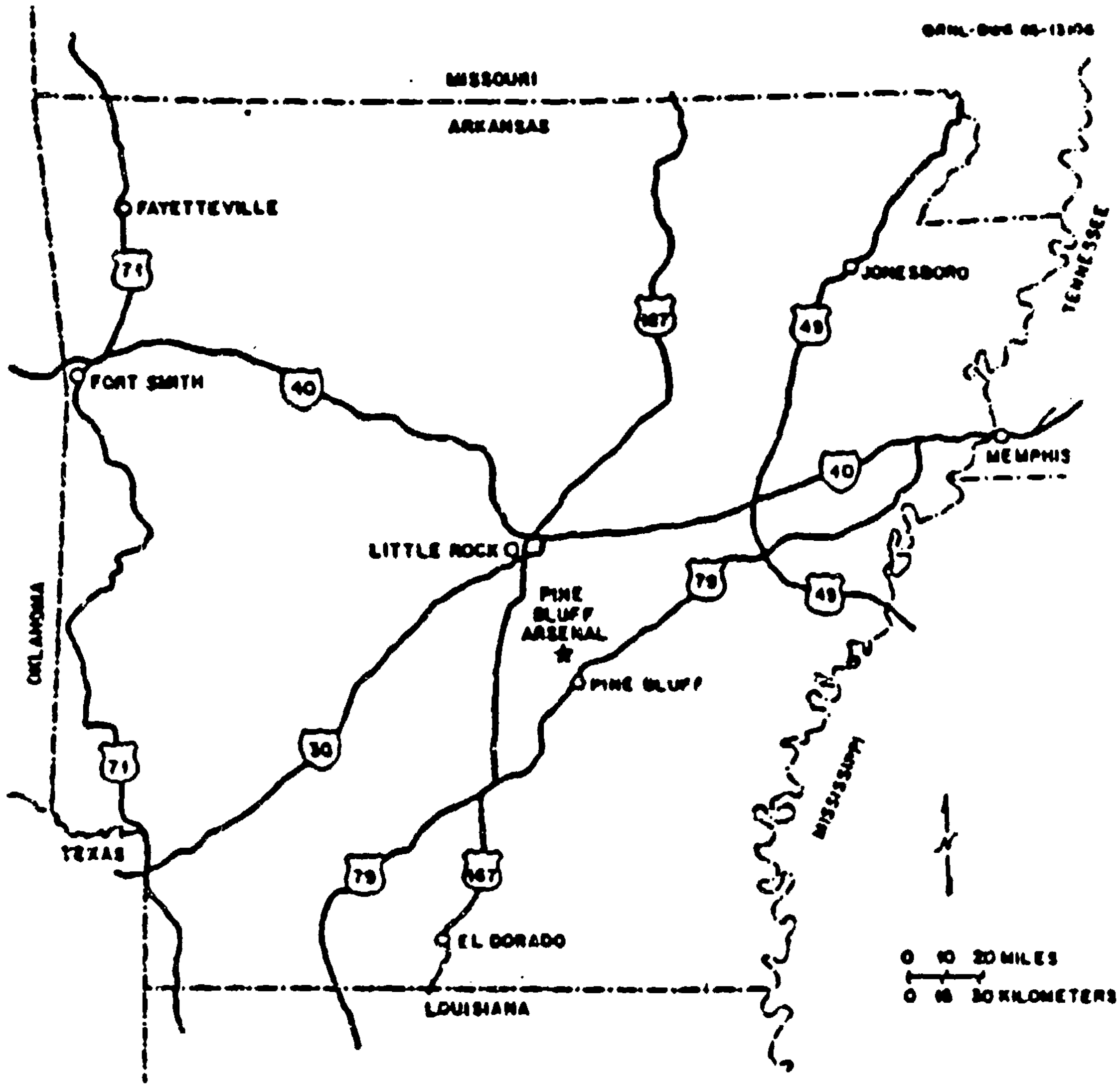

Fig. D-10. Arkansas state map showing the location of PBA

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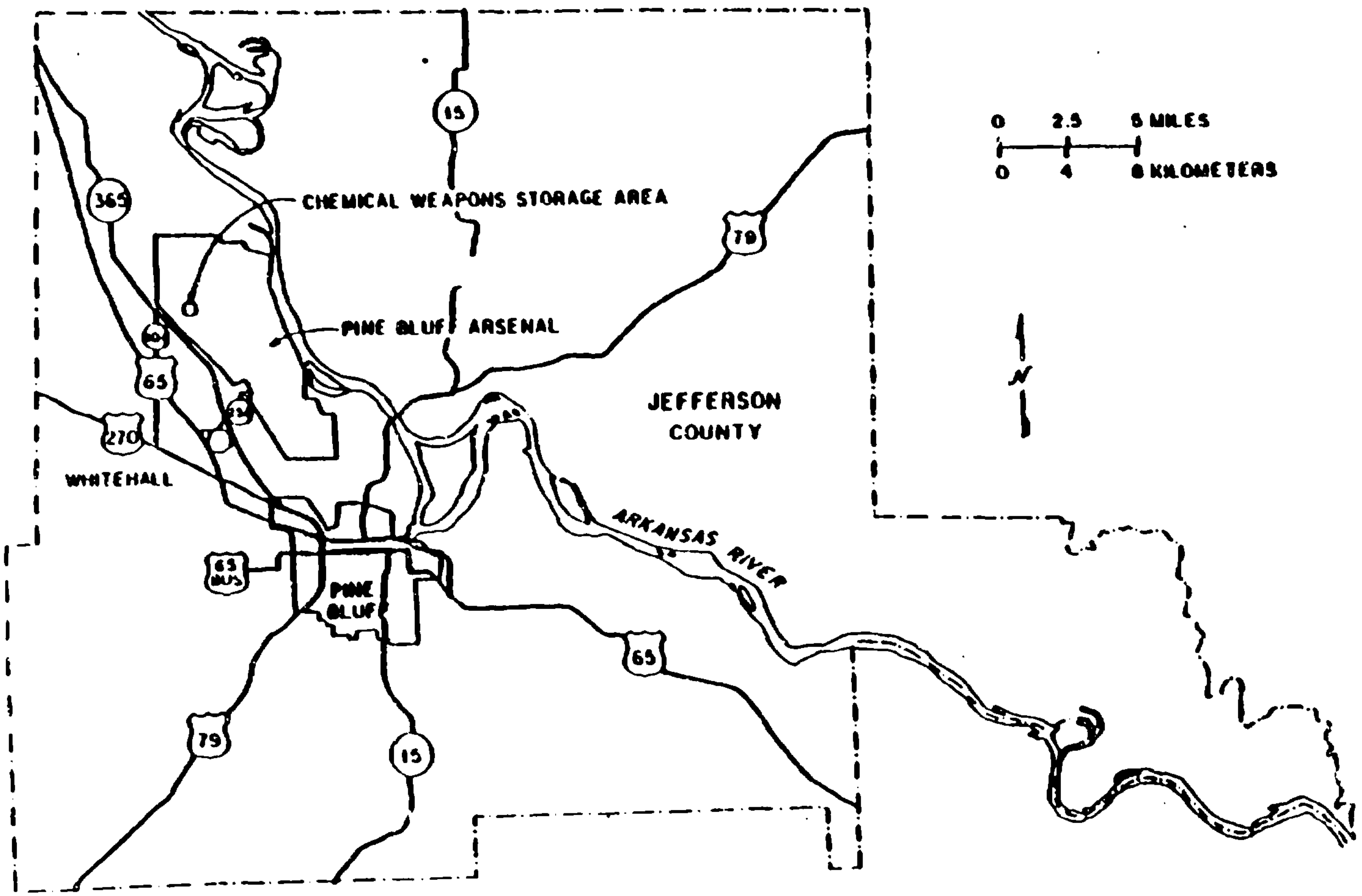

Fig. D-11. County map showing the location of PBA

There is a helipad onsite about 2 miles away from the chemical munition storage area boundary. The flight frequency was estimated to be 30 or less flights a month (Ref. D-1).

TABLE D-5
EARTHQUAKES IN THE VICINITY OF THE PBA SITE[a]
(Chronological Listing)

Year	Month	Day	Location	Epicentral Intensity (MMI)
1911	3	31	33.8N, 92.2W	VI
1918	10	4	34.7N, 92.3W	V
1930	11	16	34.3N, 92,8W	V
1939	6	19	34.1N, 93.1W	V
1967	6	4	33.5N, 90.8W	VI
1967	6	29	33.5N, 90.8W	V
1969	1	1	34.3N, 92.6W	VI
1974	2	15	33.9N, 93.0W	V
1974	12	13	34.5N, 91.8W	V
1978	9	23	33.6N, 91.89W	V
1982	1	21	35.1N, 92.2W	V
1982	1	24	35.2N, 92.2W	V
1982	2	24	35.1N, 92.2W	V
1982	3	1	35.1N, 92.2W	V
1983	1	19	35.1N, 92.2W	V

[a]Earthquakes within a 100 mile (160 km) radius of the Pine Bluff site as provided by the National Geophysical Data Center, NOAA. Records believed to be duplicates are reported only once. Source: Ref. D-1.

D.1.6. PUEBLO DEPOT ACTIVITY

The Pueblo Depot Activity (PUDA) is under the command of the Tooele Army Depot. As shown in Figs. D-12 and D-13, the installation lies east of the city of Pueblo, Colorado and north of the Arkansas River. The mission of PUDA facilities is to operate a reserve storage and maintenance function providing for (1) limited receipt, storage, and issue of assigned commodities; (2) depot maintenance of assigned commodities; (3) limited maintenance of facilities to prevent deterioration of the ammunition stockpile; (4) operation of a calibration service for an assigned geographical area; (5) demilitarization and disposal of deteriorated explosives and munitions; (6) ammunition surveillance; (7) small arms clipping and linking; (8) operation of the Function/Trace Test Range; and (9) missile maintenance/production.

The chemical storage area at PUDA is located in the northeast corner of the depot in the G-block storage area. The following munitions are stored at PUDA: 155-mm projectiles, 105-mm cartridges and projectiles, and 4.2-in. mortar projectiles. All munitions are stored in 80-ft igloos.

Table D-6 summarizes earthquake activity in the vicinity of the PUDA site.

The airspace at the PUDA is not restricted. There is a private airport (Youtsey) a few miles south of the depot. The nearest public airport is Pueblo Memorial which is located 6 miles west of the boundary of the depot. This airport has four runways, the longest being 10,500 ft. Pueblo Memorial is used as a training airport for both commercial and military aircraft. Low altitude federal airways V10, V19, V81, V83, V244, and V389 all pass within a few miles of the depot, as do high altitude jet routes J17 and J28.

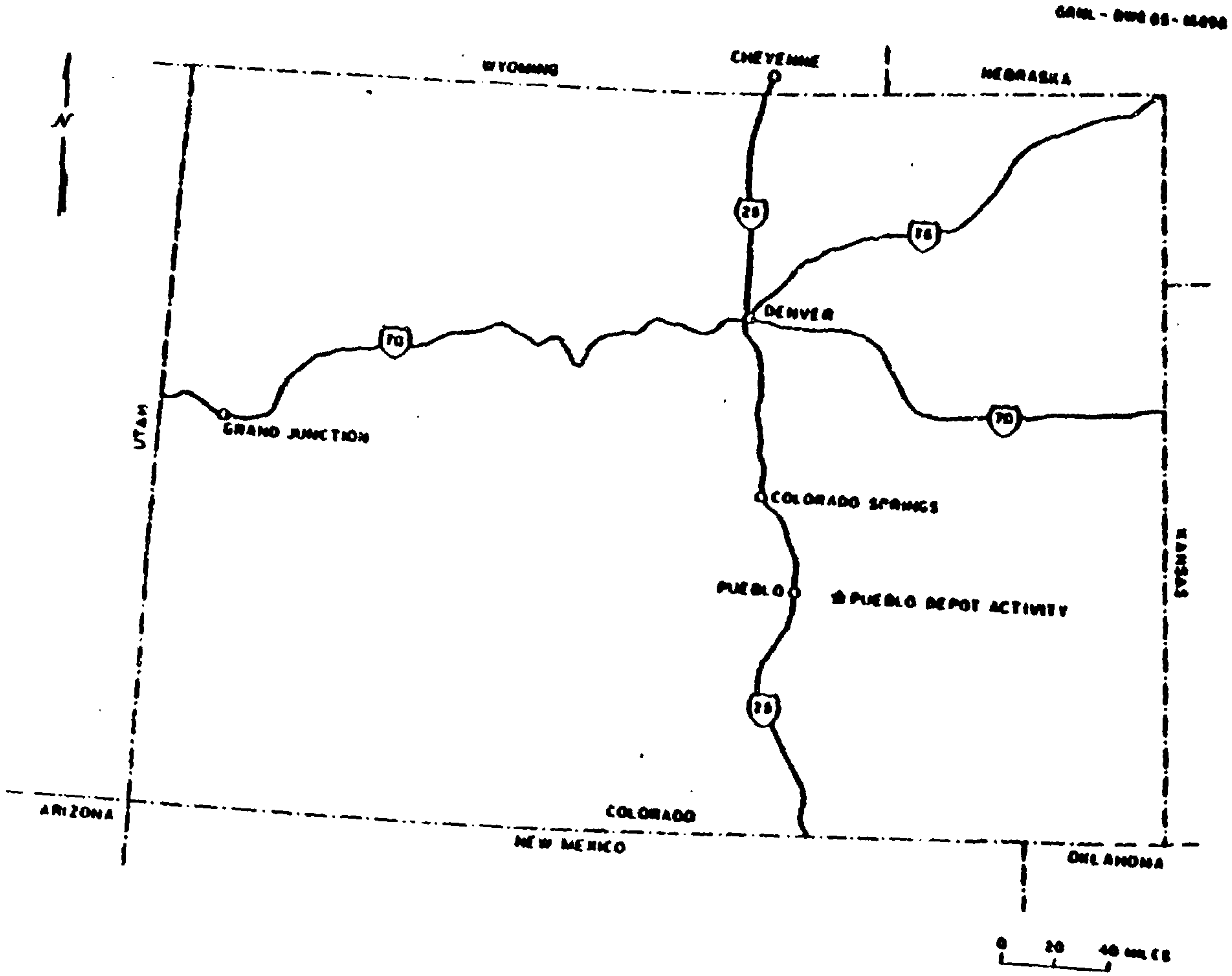

Fig. D-12. Colorado state map showing the location of PUDA

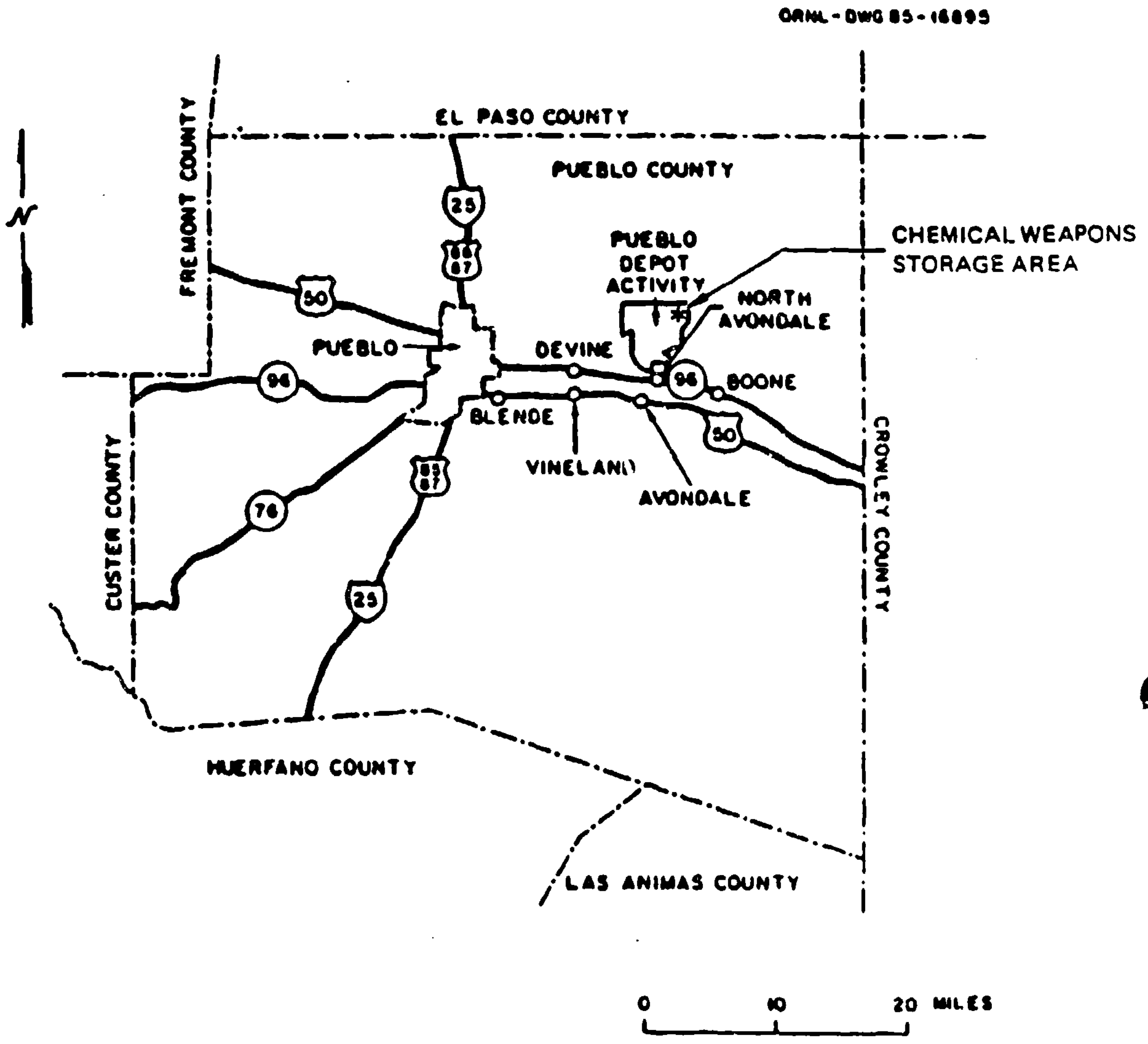

Fig. D-13. County map showing the location of PUDA

TABLE D-6
EARTHQUAKES IN THE VICINITY OF THE PUDA SITE
(Ordered By Distance From Site)

Year	Month	Day	Location	MMI	Distance from Site (km)
1963	11	13	38.3N, 104.6W	IV	22
1870	12	4	38.5N, 104.0W	VI	37
1955	11	28	38.2N, 103.7W	IV	58
1925	2	18	38.2N, 105.1W	IV	67
1888	10	23	38.1N, 105.2W	IV	78

Data provided by the National Geophysical Data Center, NOAA.

D.7. TOOELE ARMY DEPOT

The Tooele Army Depot (TEAD) is located in north central Utah southwest of Salt Lake City as shown in Figs. D-14 and D-15. The Army Depot consists of two separate areas, North and South. The chemical agent storage and demilitarization operations are located in the South Area. The mission of TEAD is to operate a supply depot providing for receipt, storage issue, maintenance and disposal of assigned commodities; and to operate other facilities such as the Chemical Agent Munitions Disposal System (CAMDS).

The chemical storage area at TEAD is located in the center of the south area. There are storage magazines, warehouse buildings, and several storage yards within the chemical agent exclusion area. The storage magazines include both 89-ft oval-arch magazines and 80-ft igloo magazines. M55 rockets, 155-mm and 8-in. projectiles, 105-mm cartridge projectiles, 4.2-in. mortar projectiles, GB and VX ton containers, M23 land mines, and weteye bombs are stored in the 80-ft igloos. MC-1 bombs, 155-mm and 105-mm projectiles are stored in the 89-ft oval-arch magazines. Ton containers containing mustard are stored outdoors. The two warehouse buildings currently are used to store VX spray tanks packaged inside TMU-28/B storage and shipping containers.

The warehouse buildings are flat-roofed, single-story structures approximately 188 ft long, 179 ft wide, and 16 ft high. Details of construction are shown in Army Corps of Engineers Drawing 201-25-65. The side walls of the buildings are single piece precast concrete panels 6 in. thick, 16 ft high, with widths varying around 30 ft. The roof is of corrugated sheet metal, supported by a steel beam support structure and steel box beam vertical support columns. The main beams are W24 x 68 steel I-beams with unsupported spans of about 30 ft. Open trusses are used to span between the main beams.

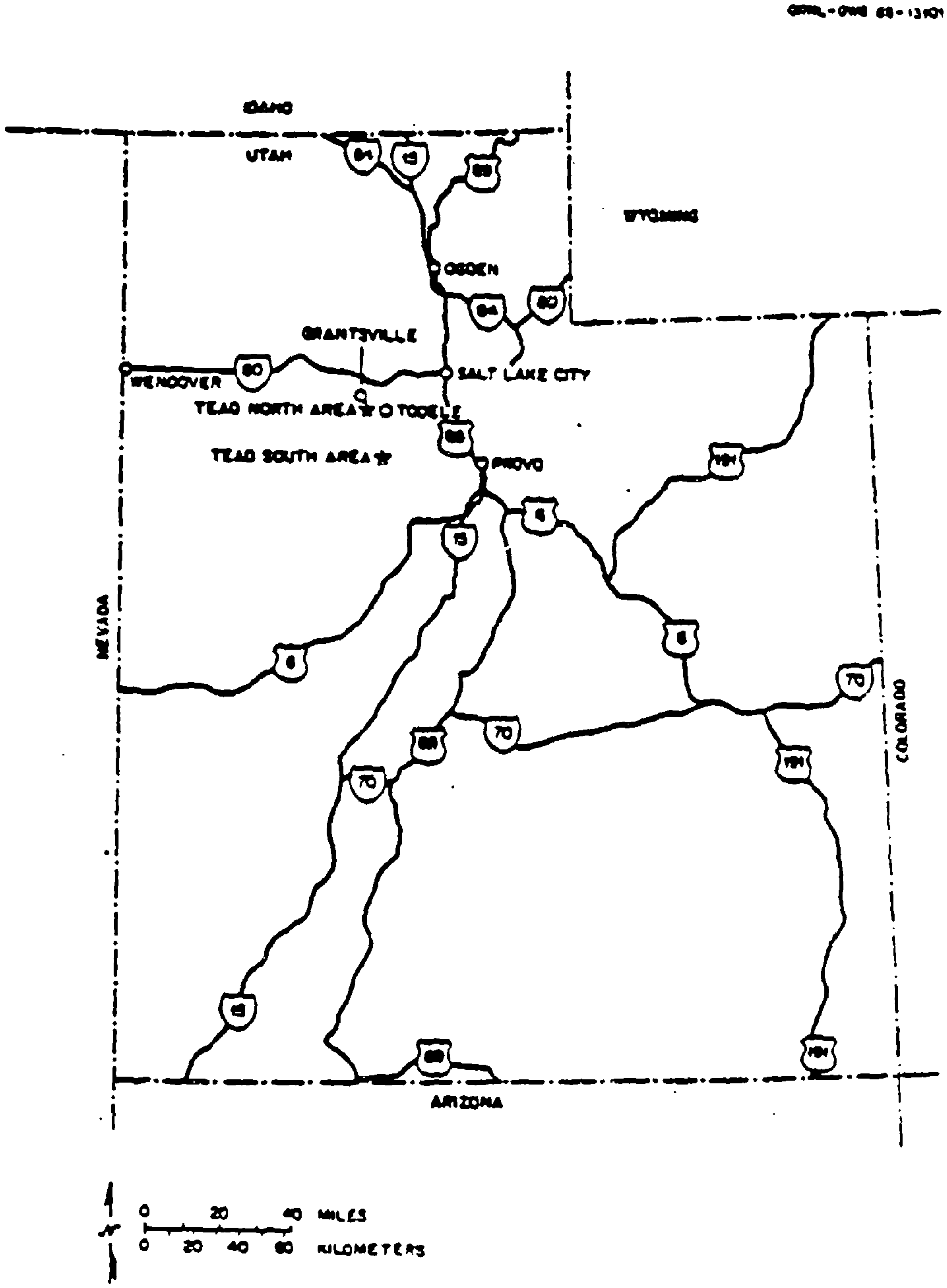

Fig. D-14. Utah state map showing the location of TEAD

ORNL DWG 85-13102R

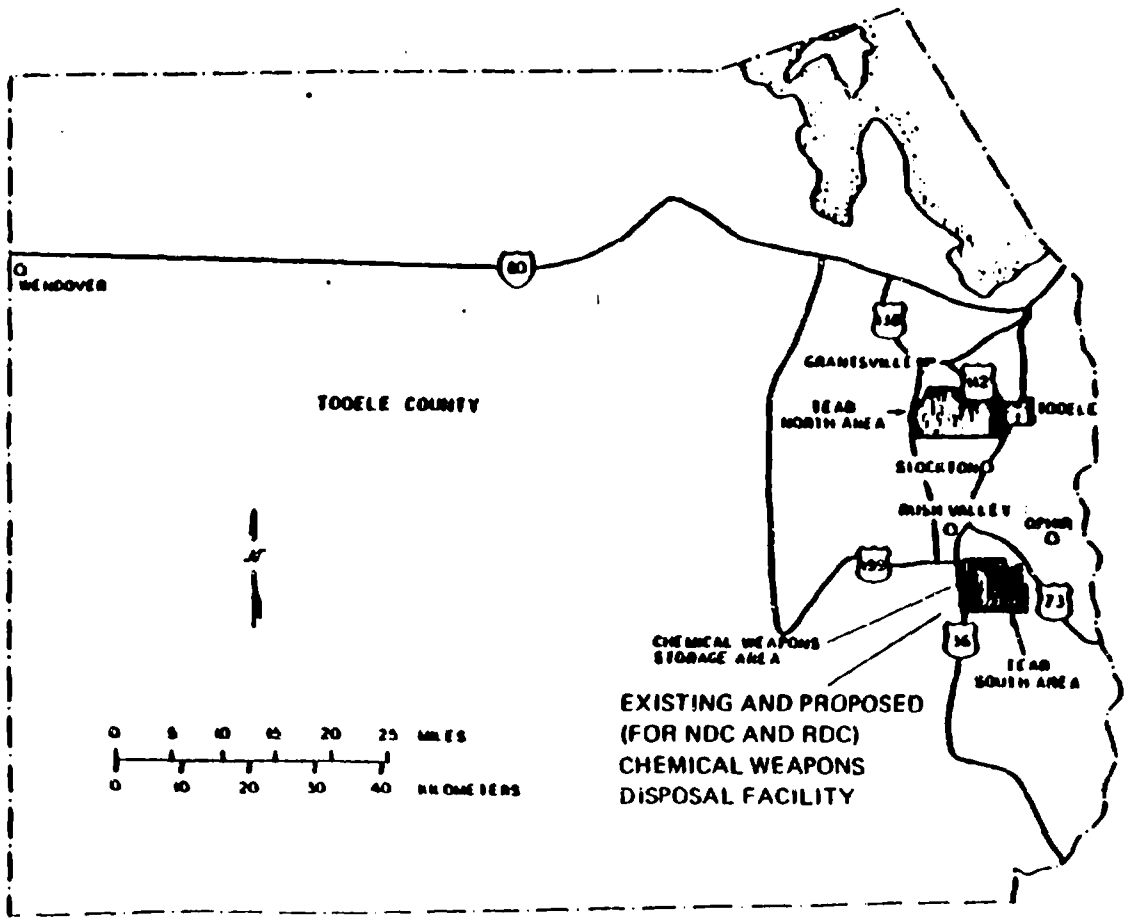

Fig. D-15. Tooele county map showing the location of TEAD

Table D-7 summarizes earthquake activity in the vicinity of the TEAD site.

The airspace over the TEAD South Area is not restricted but pilots are requested (for reasons of national security) to avoid flying below 6400 ft over this area for a radius of 3 nautical miles (3.5 statute miles).

Tooele Municipal Airport is the nearest airport to the site. It is located 14 miles north of the site and is not expected to present a significant hazard.

There are two low altitude federal airways in the vicinity of the TEAD South Area: V257, three miles to the west, and V253, 17 miles to the northeast. High altitude airways are not considered a hazard for this site.

There is a helipad located near the administrative building approximately 3 miles from the chemical munition storage area. The helipad is used infrequently. The number of flights per month is estimated to be 15.

TABLE D-7
EARTHQUAKES IN THE VICINITY OF THE TEAD SITE[a]
(Chronological Listing)

Year	Month	Day	Location	Epicentral Intensity (MMI)
1853	12	1	39.7N, 111.8W	V
1876	3	22	39.5N, 111.5W	VI
1880	9	17	40.8N, 112.0W	V
1884	11	10	40.8N, 111.9W	VIII
1894	1	8	39.7N, 113.4W	V
1894	6	8	39.9N, 113.4W	V
1894	7	18	41.2N, 112.0W	VII
1899	12	13	41.0N, 112.0W	V
1900	8	1	39.8N, 112.2W	VII
1906	5	24	41.2N, 112.0W	V
1909	11	17	41.7N, 112.2W	V
1910	5	22	40.8N, 111.9W	VII
1914	4	8	41.2N, 111.6W	V
1915	7	15	40.3N, 111.7W	VI
1915	7	30	41.7N, 112.1W	V
1915	8	11	40.5N, 112.7W	V
1915	10	5	40.1N, 114.0W	V
1916	2	5	40.0N, 111.7W	V
1920	9	18	41.5N, 112.0W	VI
1920	9	19	41.5N, 112.0W	VI
1920	11	20	41.5N, 112.0W	VI
1934	3	12	41.5N, 112.5W	VIII
1934	4	14	41.5N, 112.5W	
1934	5	6	41.7N, 113.0W	
1938	7	9	40.5N, 111.6W	V
1938	6	30	40.5N, 111.6W	VI
1943	2	22	40.4N, 111.8W	VI
1947	3	7	40.5N, 111.6W	V
1949	3	7	40.5N, 111.6W	V
1950	5	8	40.0N, 111.5W	V
1951	8	12	40.2N, 111.4W	V
1952	9	28	40.3N, 111.5W	V
1953	5	24	40.5N, 111.5W	VI
1955	2	4	40.5N, 111.6W	V
1955	5	12	40.4N, 111.6W	V
1958	2	13	40.5N, 111.5W	VI
1958	11	28	39.4N, 111.5W	V
1958	12	1	40.5N, 112.5W	V
1958	12	2	40.5N, 112.5W	V
1961	4	16	39.1N, 111.5W	VI
1962	9	5	40.7N, 112.0W	VI
1963	7	7	39.6N, 111.9W	VI
1963	7	9	40.0N, 111.2W	
1963	7	10	39.9N, 111.4W	V
1965	5	11	41.0N, 111.5W	

TABLE D-7 (Continued)

Year	Month	Day	Location	Epicentral Intensity (MMI)
1966	5	23	39.2N, 111.4W	
1967	2	16	41.3N, 113.3W	V
1967	9	24	40.7N, 112.1W	V
1967	12	7	41.3N, 111.7W	V
1968	1	16	39.3N, 112.2W	V
1968	11	17	39.5N, 110.9W	V
1969	5	23	39.0N, 111.8W	V
1970	4	14	39.6N, 110.7W	V
1970	10	25	39.1N, 111.3W	V
1972	10	1	40.5N, 111.3W	VI
1972	10	16	40.4N, 111.0W	V
1973	7	16	39.1N, 111.5W	V
1977	11	28	41.3N, 111.6W	V
1978	2	28	40.7N, 112.2W	V
1978	3	9	40.7N, 112.0W	VI
1978	3	13	40.7N, 112.0W	V
1980	5	24	39.9N, 111.9W	V
1981	2	20	40.3N, 111.7W	V
1981	5	14	39.4N, 111.0W	V
1983	10	8	40.7N, 111.9W	VI

(a)Earthquakes within a 100-mile radius of TEAD as provided by the National Data Center, NOAA. Records believed to be duplicated are reported only once. Source: Ref. D-1.

D.1.8. UMATILLA DEPOT ACTIVITY

The Umatilla Depot Activity (UMDA) is under the command of TEAD. As shown in Figs. D-16 and D-17, the installation is located in Umatilla and Marrow Counties in northeastern Oregon, near the south shore of the Columbia River, west of Hermiston, Oregon. UMDA's mission is to operate a reserve storage depot activity under the command of TEAD providing care and preservation for and minor maintenance of assigned commodities.

The storage area is located at the northern edge of the installation. Eighty-foot igloo magazines and warehouses are used to store the chemical munition stockpile of 155-mm and 8-in. projectiles, M55 rockets, M23 land mines, bombs, spray tanks, and ton containers. Warehouses are used to store ton containers containing mustard agent. The magazines are spaced 400 ft apart.

The warehouses are butler type buildings connected by a roof with a steel structure and aluminum siding (single sheet). The two buildings are defined as transitory structures, approximately 154 ft wide (total for both buildings) and 300 ft long.

Table D-8 summarizes earthquake activity in the vicinity of the UMDA site.

The UMDA airspace is not restricted. The nearest active airfield to the Umatilla site is Hermiston Municipal Airport approximately 12 miles from the depot. With one 4000-ft runway, its capabilities are limited to aircraft up to the size of corporate jets. The Tri-Cities Airport in Pasco, Washington, with a maximum runway length of 7700 ft, is approximately 30 miles from the depot. In general, it does not handle military aircraft. There is also a paved runway on the UMDA site capable of handling small aircraft up to the size of a Beech U-21 light utility aircraft. The nearest military airfields are in Spokane, Washington; Moses Lake, Washington; and Mt. Home, Idaho.

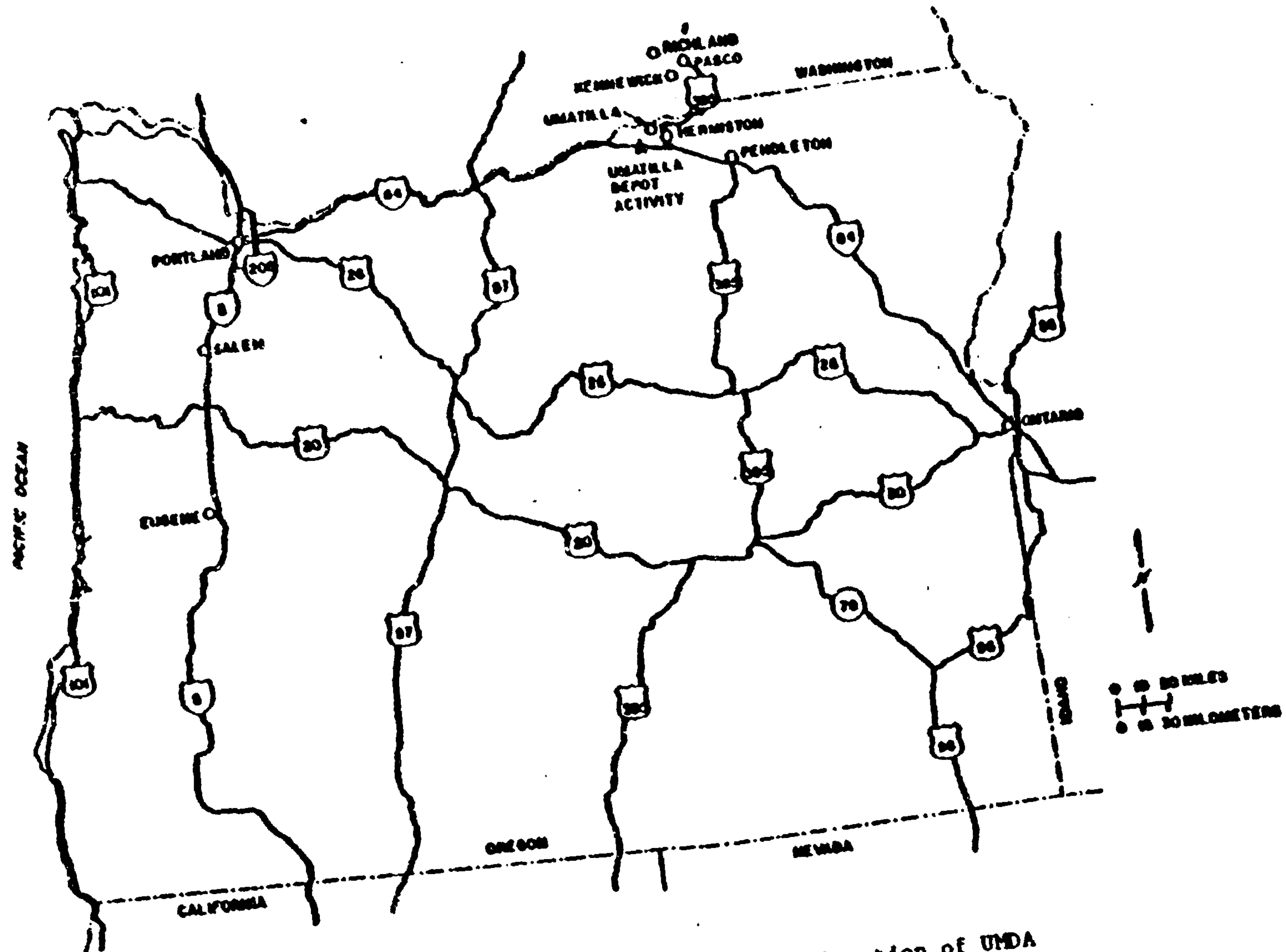

Fig. D-16. Oregon state map showing the location of UMDA

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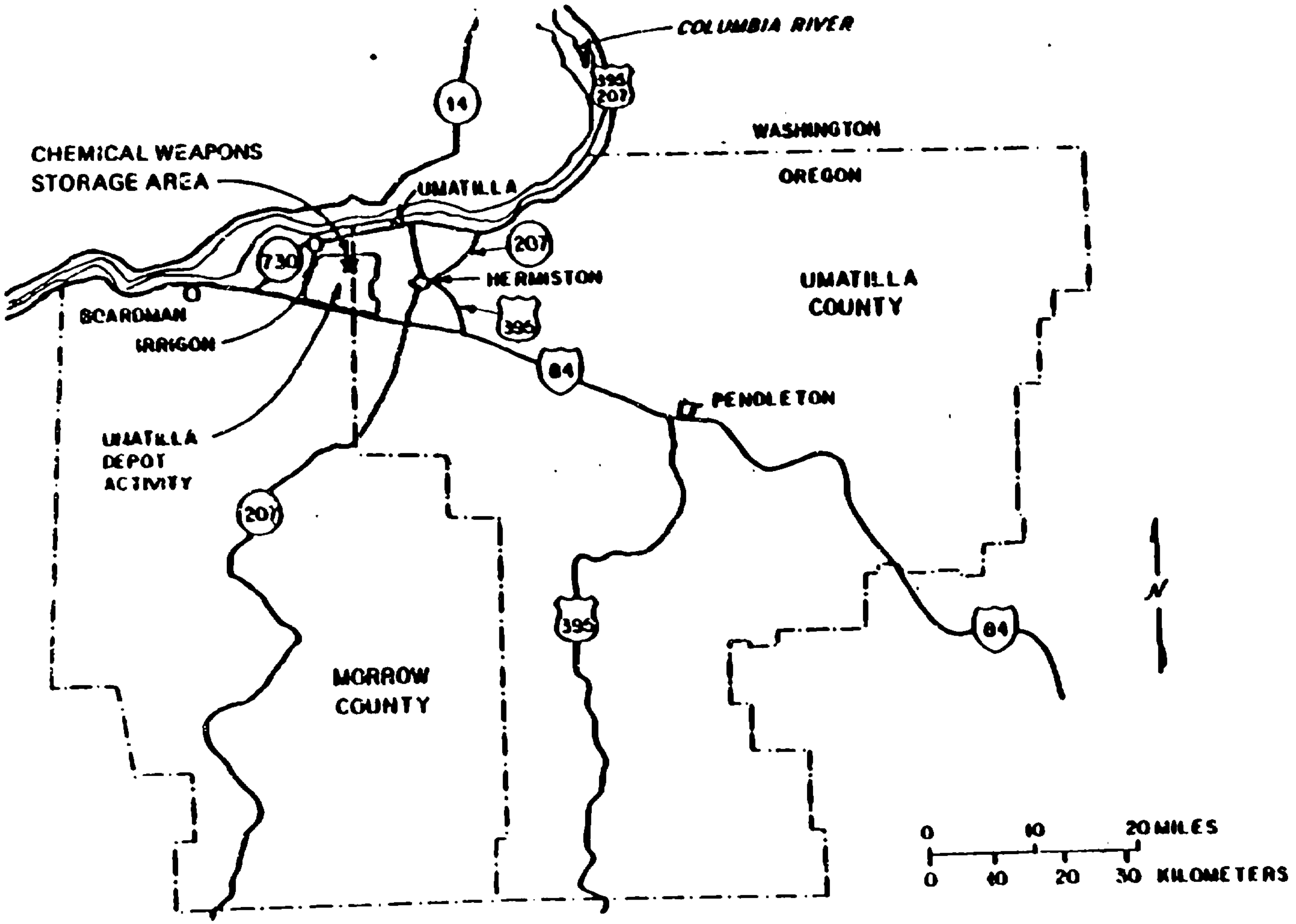


Fig. D-17. County map showing the location of UMDA

TABLE D-8
EARTHQUAKES IN THE VICINITY OF THE UMDA SITE[a]
(Chronological Listing)

Year	Month	Day	Location	Epicentral Intensity (MMI)
1893	3	5	Umatilla, OR	VI
1918	11	1	46.7N, 119.5W	V to VI
1921	9	14	Dixie, WA	V to VI
1924	1	6	Walla Walla, WA	IV
1924	1	6	Milton Weston, OR	V
1924	5	26	Walla Walla, WA	IV
1926	4	23	Walla Walla, WA	IV
1936	7	15	46.0N, 118.5W	VII
1936	7	18	46.0N, 118.3W	V
1936	7	20	Freewater, OR	IV
1936	8	4	45.8N, 118.6W	V
1936	11	17	Walla Walla, WA	III
1937	2	9	Walla Walla, WA	IV
1937	6	4	Walla Walla, WA	IV
1938	8	11	Milton, OR	IV
1938	10	27	Milton, OR	IV
1944	9	1	Walla Walla, OR	IV
1945	9	22	Walla, Walla, OR	IV
1951	1	7	McNary, OR	V
1959	1	20	Milton-Freewater, OR	V
1959	11	9	Heppner, OR	IV
1971	10	25	46.7N, 119.5W	IV

Earthquakes within a 50- to 60-mile radius of the Umatilla site, abstracted from Table 2.5-2, UNI-M-90, "N Reactor Updated Safety Analysis Report," United Nuclear Industries, Inc., February 28, 1978. Source: Ref. D-1.

The Medium Attack Tactical Electronic Warfare Wing bombing range is located 10 miles to the southwest of UMDA chemical munitions exclusion area. This area is a restricted airspace (Restriction numbers R-5701, R-5704, R-5706) in which the Navy holds bombing exercises. Grumman A-6 aircraft, in groups of four, fly about 14 sorties during the day and ten sorties at night, five days a week, dropping inert 25-lb bombs and, occasionally, 500- to 1000-lb inert bombs. Per the guidelines of Ref. D-8, this is not considered a significant threat. There are two low altitude federal airways in the general area of the depot: V-4 and V-112. Three high altitude airways (J-16, J-20, and J-54) cross within 6 miles of the depot toward Pendleton, Oregon.

The installation provides limited maintenance to preclude deterioration of facilities and retains limited shipping and receiving capabilities.

D.1.9. REFERENCES

D-1. Science Applications International Corporation, "Probabilities of Selected Hazards in Disposition of M55 Rockets," U.S. Army Toxic and Hazardous Materials Agency, M55-CS-2, November 1985.

D-2. Jeppesen, "United States High Altitude Enroute Charts," U.S. (HI) 1-5, March 1986.

D-3. "Aircraft Hazards," U.S. Nuclear Regulatory Commission Standard Review Plan 3.5.1.6, NUREG-0800, Rev 2, July 1981.

APPENDIX E
(Deleted)

APPENDIX F
MUNITION FAILURE THRESHOLDS

F.1. MUNITION FAILURE THRESHOLDS

The munition stockpile is comprised of 11 different munition types. This appendix contains a description of the physical characteristics of each munition type, a description of their existing storage configurations, and a description of the munition failure thresholds that are important for quantifying the agent release associated with each accident scenario. The failure thresholds discussed herein are the thresholds for accidental burster detonation, the thermal threshold for hydraulic rupture of the agent compartment, and the mechanical failure thresholds which lead to failure of the agent compartment.

F.1.1. DESCRIPTION OF CHEMICAL MUNITIONS

The chemical stockpile is presently made up of the following munitions:

1. 8-in. artillery projectiles. The 8-in. projectiles are filled with the nerve, agent either GB or VX. They are stored without fuzes, but they may be stored with or without bursters. The 8-in. projectiles are stored on wooden pallets with six rounds per pallet.

2. 155-mm artillery projectiles. The 155-mm projectiles may contain GB, VX, or mustard. They are stored without fuzes, but they may be with or without bursters. The 155-mm projectiles are stored on wooden pallets with eight rounds per pallet.

3. 105-mm artillery rounds. The rounds are filled with either mustard or GB. The rounds may be stored as bare projectiles

on wooden pallets, with 24 rounds per pallet, and with 2 pallets butted together and secured with steel banding, or as cartridges in fiber tubes, with two tubes in a wooden field box, and with either 12 or 15 boxes unitized on a skid based wooden pallet. The cartridges include burster, fuze, cartridge case and propellant.

4. 4.2-in. mortar projectiles. All are filled with mustard agent. The mortars may be stored with burster, fuze, and propellant in fiber tubes, with two tubes in a wooden field box, with either 36 boxes on a wooden pallet, or 24 boxes on a wooden skid base. The mortars may also be stored without burster and fuze in wooden pallets.

5. M23 land mines. All land mines are filled with VX. The mines are burstered, and are packaged three to a steel drum. Mine activators and fuzes are packaged separately in the same drum. Twelve drums are contained on a wooden pallet.

6. M55 rockets. The M55 rockets are filled with either GB or VX. The rockets are equipped with fuzes and bursters which contain explosives. Propellant is also built into the motor of the rocket. The rocket casing is made of aluminum which may slowly react with nerve agent to form hydrogen gas. Pressure buildup in some of the rockets has caused a leakage problem.

The rockets are individually packaged in fiberglass shipping tubes with metal end caps. Fifteen containers with rockets are packed on a wooden pallet.

7. MC-1 750-lb bombs filled with GB. The MC-1 bombs are stored without explosive components on wooden pallets with two bombs per pallet.

8. MK-94 500-lb bombs filled with GB. The MK-94 bombs are stored without explosive components in individual MK-410 storage and shipping containers.

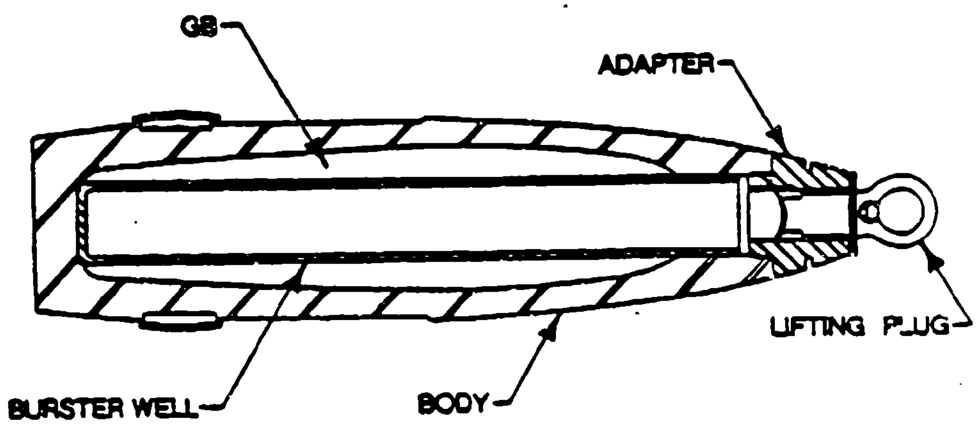
9. MK-116 (Weteye) 600-lb Navy bombs filled with GB. These bombs are stored without explosive components in individual MK-398 storage and shipping containers.

10. TMU-28/B airborne spray tanks filled with VX. They were designed for releasing chemical agent from slow-traveling, low-flying aircraft. The spray tanks are stored in individual CNU-77/E23 storage and shipping containers.

11. Ton containers. A large fraction of the chemical stockpile is stored in bulk form in cylindrical steel containers referred to as ton containers. The ton containers may contain GB, VX, or mustard. The ton containers are not palletized, but are banded together in clusters.

Drawings and photographs of each of the above munitions are shown in Figs. F-1 through F-35.

During transportation of the munitions, either to an onsite disposal facility or an offsite disposal facility, the munitions are placed in a protective shipping container or package. The shipping package has not yet been designed, but criteria for the structural and thermal protection to be provided during munition transport are defined in Ref. F-1.



LENGTH	35.1 in.
DIAMETER	8 in.
TOTAL WT.	199 lb.
AGENT	GB
AGENT WT.	14.5 lb.
FUZE	None
BURSTER	M83
EXPLOSIVE	Comp B
EXPLOSIVE WT.	7.0 lb.
SUPP. CHARGE	0.3 lb. TNT
PROPELLANT	None
PROPELLANT WT.	N/A
PRIMER	None
QD/SCG	8A
PACKAGING	6 rounds/wooden pallet

PROJECTILE, 8 INCH, GB, M426

Fig. F-1. Projectile, 8-in., GB, M426